PB84-189943

Methodology for Development of an Independent Combustion Source NOx Inventory and Its Application to 150 Counties in the Northeastern United States

PEDCo-Environmental, Inc., Cincinnati, OH

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

Apr 84

U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-189943

EPA-600/7-84-059
April 1984

METHODOLOGY FOR DEVELOPMENT OF AN INDEPENDENT COMBUSTION SOURCE NO_x INVENTORY

And Its Application to 150 Counties in the Northeastern United States

by

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Task Orders 68 and 78

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CINCINNATI, OHIO 45268

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/7-84-059	2.	3. RECIPIENT'S ACCESSION NO. PB84 189943
4. TITLE AND SUBTITLE Methodology for Development of an Independent Combustion Source NOx Inventory and Its Application to 150 Counties in the Northeastern United States		5. REPORT DATE April 1984
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Michael F. Szabo and Paul W. Spaite*		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS PEDCo. Environmental, Inc. 11499 Chester Rd. Cincinnati, OH 45246-0100		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-3173, Tasks 68 and 78; 68-02-3197*
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 12/81 - 8/83
		14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES IERL-RTP project officer is Joshua S. Bowen, Mail Drop 65, 919/541-2470. (*) Paul W. Spaite Co., 6315 Grand Vista Dr., Cincinnati, OH 45213.

16. ABSTRACT

The report gives results of the demonstration of a new methodology for developing a combustion source fuel use and emissions inventory. The demonstration area encompassed 150 counties within a 200 mi (320-km) radius of the Adirondack Mountains in New York State, believed to be representative of the Northeastern U.S. A complete combustion inventory of nitrogen oxides (NOx) emissions was developed for the 150 counties. All sectors (residential, commercial, transportation, utility, and industrial) were included. In the industrial sector, the methodology entailed: 1) identifying all major combustion processes and associated equipment, and 2) developing NOx emission factors. This approach produced a list of 28 facilities and 73 processes, believed to include all significant combustion sources in the 150-county area. An approach was also developed for treating all fuel consumption not accounted for by installations that include major combustion processes. The latter block of fuel consumption was translated into 'residual' industrial area source NOx emissions. As intended, the project demonstrated fully the essential elements of a methodology that would allow development of a county-by-county NOx inventory for all fuel burning in all or any part of the U.S., without resorting to user surveys or inventories based on such surveys.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Nitrogen Oxides Combustion Inventories Fuels	Pollution Control Stationary Sources	13B 07B 21B 15E 21D

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 229
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

NOTICE

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ABSTRACT

This study was performed to demonstrate a new methodology for the development of a combustion source fuel use and emissions inventory. The demonstration area encompassed 150 counties within a 200-mile radius of the Adirondack Mountains in New York State, which was believed to be representative of the Northeastern United States.

A complete combustion inventory of nitrogen oxides (NO_x) emissions was developed for the 150 counties. All sectors (residential, commercial, transportation, utility, and industrial) were included. In the industrial sector, the methodology entailed: 1) the identification of all major combustion processes and associated equipment, and 2) development of NO_x emission factors. This approach produced a list of 28 facilities and 73 processes, which is believed to include all significant combustion sources in the 150-county study area. An approach was also developed for treating all fuel consumption not accounted for by installations that include major combustion processes. The latter block of fuel consumption was translated into "residual" industrial area source NO_x emissions.

As intended, the project demonstrated fully the essential elements of a methodology that would allow development of county-by-county NO_x inventory for all fuel burning in all or any part of the United States without resorting to user surveys or inventories based on such surveys. The data base it establishes also can be used to calculate other combustion-related emissions.

Although the procedures of this methodology have not been fully optimized in this study, they are straightforward and well documented, and they can be easily modified as new data are uncovered.

Study results showed that area sources account for 92 percent of the fuel consumption (excluding utilities) and 64 percent of NO_x emissions (including utilities) in the study area. Transportation is the dominant area source NO_x contributor. Boilers are the dominant point sources of NO_x emissions, and residual oil accounts for 52 percent of the industrial boiler fuel burned in this area.

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ACKNOWLEDGMENT

The authors acknowledge the contributions to development of this report by Thomas K. Corwin and Mary Taft-Frank. The report incorporates copyrighted material, developed by coauthor Spaite under EPA contract. The authors appreciate the cooperation and assistance provided by EPA Project Officer Joshua S. Bowen.

SECTION 1

INTRODUCTION

This report presents the results of a study to investigate and demonstrate a new approach to development of combustion emissions inventories. Fossil fuel consumption and nitrogen oxides (NO_x) emissions were estimated for all energy-consuming sectors; i.e., utility sources, industrial combustion sources (including direct-fired processes and boilers), residential and commercial combustion sources, and transportation-related sources.* A study area in the United States encompassing 150 counties within a 200-mile radius of the Adirondack Mountains in New York State was chosen to implement the methodology. The approximate study area is shown in Figure 1-1.

The results reported here combine data from preliminary work performed by PEDCo Environmental and the Paul W. Spaite Company in the development of a methodology for conducting an inventory of combustion sources. The objectives of this preliminary work were to make the inventory methodology comprehensive in coverage, accurate in its location of major process sources, and as accurate as possible with respect to fuel consumption computations and

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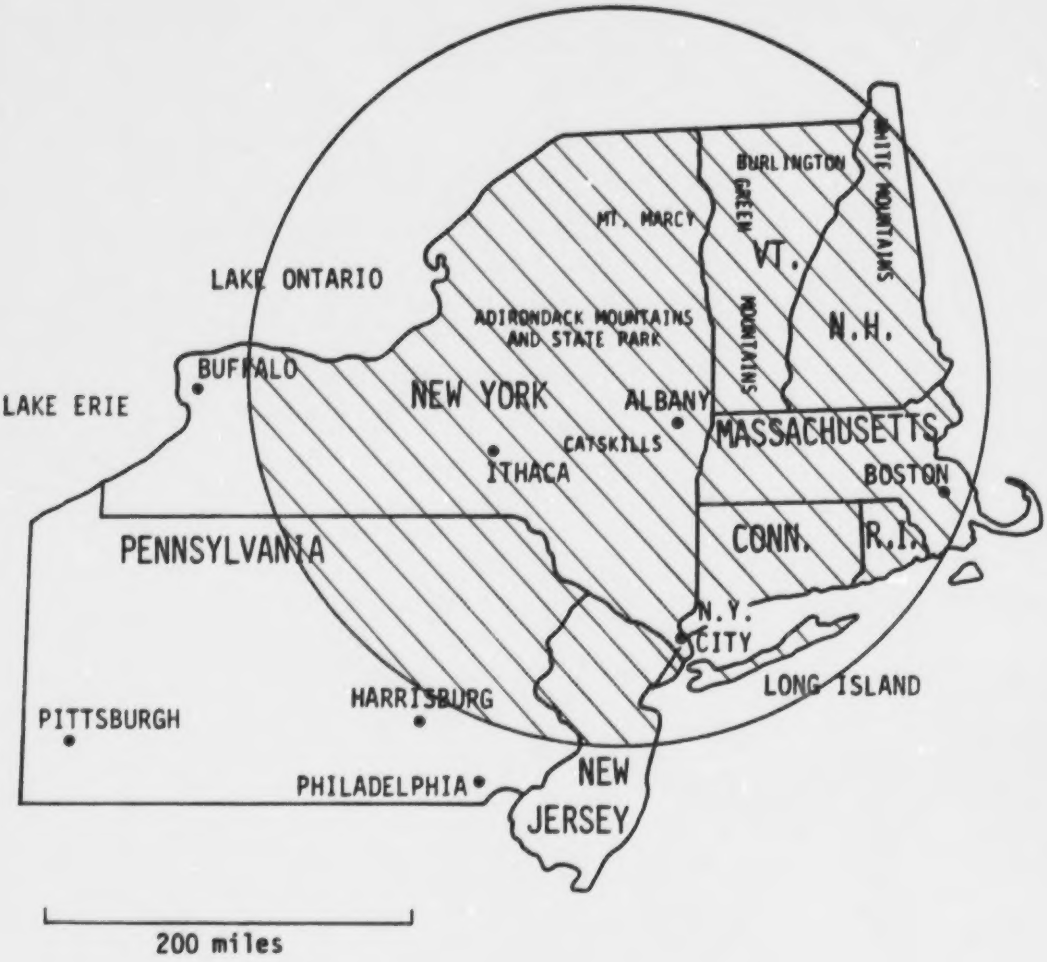
* Because utility sources have been much studied and are known to be well documented, an actual inventory was not developed for this sector. Emissions estimates for the study area were obtained, however, from the National Emissions Data System (NEDS) and are included in the results for comparison purposes.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GREEN MOUNTAINS
VT.
WHITE MOUNTAINS
N.H.
MASSACHUSETTS
BOSTON
CONN.
R.I.
N.Y. CITY
LONG ISLAND
PENNSYLVANIA
PITTSBURGH
HARRISBURG
PHILADELPHIA
NEW JERSEY
200 miles

Figure 1-1. Illustration of the 150-county study area (shaded).

derived pollution estimates. The current study builds upon this previous effort and successfully demonstrates that open literature sources can be used to locate fuel burning facilities, to determine the major processes used, and to estimate the quantities of fuel burned.

The approach as it was originally conceived was reported in "A Comprehensive Inventory of Air Pollution Sources,"* issued April 25, 1982 and revised June 24, 1982 (see Appendix A). In the latter study, several types of major fuel-consuming facilities were analyzed to test the methodology. Table 1-1 presents a list of the facilities examined. The fuel consumption data presented illustrate the wide range found in major combustion processes. Because the methodology was able to handle the diversity of processes represented in Table 1-1, the investigators believed it should also be applicable to other processes that might be identified later in an expanded project.

This study is designed to demonstrate the methodology by developing a complete NO_x inventory for 150 counties in the Northeastern United States. This represents an expansion of previous work in several ways:

- It entailed the identification of other combustion processes that could be considered "major."
- It was necessary to find or develop NO_x emission factors for all types of combustion equipment.

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* Spaite, P. W. A Comprehensive Inventory of Air Pollution Sources. Draft report April 25, 1982.

TABLE 1-1. ILLUSTRATIVE EXAMPLES OF FUEL CONSUMPTION FOR MAJOR COMBUSTION SOURCES[1]

Facility	Fuel, 10^{12} Btu/yr	
Power plant (400 MW capacity)		20.3
Integrated steel plant (raw steel capacity, 3,030,000 tons/yr)		13.8
Sinter plant	0.5	
Coke plant	4.2	
Blast furnace stoves	5.0	
Basic oxygen furnace	0.4	
Electric furnace	Neg.[a]	
Soaking pits	2.1	
Continuous casting	0.1	
Reheating furnace	1.5	
Refinery (crude capacity, 64,000 bbl/day)		7.3
Atmosphere distillation	2.2	
Vacuum distillation	1.2	
Catalytic cracking	0.8	
Catalytic reforming	1.1	
Hydrorefining	0.3	
Hydrotreating	0.3	
Alkylation	0.2	
Aromatics manufacture	1.2	
Ammonia plant (capacity 86,000 tons/yr) (example of a major chemical plant)		1.3
Brick plant - capacity 42 x 10^6 tons/yr		0.6
Glass plant - capacity 13 x 10^6 tons/yr		0.3
Lime kiln - capacity 690,000 tons/yr		5.9
Zinc plant - 1980 production 71,700 tons		2.0
Kraft pulp mill - capacity 530 tons/day		3.3

[a] Negligible.

- It required the development of a methodology for treating all fuel consumption not accounted for by installations that use major combustion processes. This block of fuel consumption was translated into NO_x emissions from "residual" industrial area sources.

The project was intended to demonstrate fully the essential elements of a methodology that would allow development of a NO_x inventory for all fuel burning in all or any part of the United States on a county-by-county basis, without having to resort to user surveys or inventories based on surveys.

This report has been developed to present the results of the demonstration. Although the methodology is described, it should be understood that it is not being offered as a recommended, optimized approach to developing inventories for the industries studied. In fact, in subsequent work utilizing this methodology (which is designed to be flexible and the subject of evolutionary development), some of the industry protocols have already been changed substantially. The quantitative results that are presented also are intended to show the reasonableness of the general approach rather than to be accepted as a firm indication of actual NO_x emissions in the study area. While the results show some interesting emission relationships, the reader should keep in mind that they represent a preliminary analysis of a small area of the country.

The contents of the balance of this report are as follows:

- Section 2 - A discussion of present inventories and the need for the work that is underway to provide supplemental information.

- Section 3 - A discussion of the approach that was used to assess industrial source combustion and how it was designed to be comprehensive in accounting for all fuel use. The methodology for each step in inventory development is also discussed.

- Section 4 - The results of the NO_x inventory presented in a series of tables that show estimates of fuel consumption and NO_x emissions from all types of combustion processes in the study area. These are analyzed from the standpoint of what is suggested relative to the potential for impact in the study area, and in terms of what was learned about the methodology during the development of the inventory.

- Section 5 - Conclusions.

SECTION 2

BACKGROUND

2.1 THE NEED FOR BETTER INVENTORY DATA

The Federal government first addressed air pollution on a national scale in the mid-1950's. Since that time the concern has been to identify and rank pollution sources from the standpoint of their contribution to overall pollution levels. Attention was initially focused on the problems perceived to be of greatest importance--first, motor vehicle emissions; then, sulfur oxides (SO_x) from power plants; and later, other major pollution sources. By the late 1960's, the most significant sources of major pollutants such as NO_x and SO_x had been identified and put in some perspective. Unfortunately, there was still no data bank that contained information on the size, location, type, and amount of pollution and other important factors for all major air pollution sources.

Work to develop a more comprehensive inventory was begun in the late 1960's and early 1970's. Impetus was provided by enactment of the Clean Air Act of 1970, which required development of State Implementation Plans, which in turn required considerably more information than was available on the population of sources within many states. The need for further information triggered source inventory activities on the part of both state and Federal groups.

In 1971, the U.S. Environmental Protection Agency (EPA) established the National Emissions Data System (NEDS) to provide a comprehensive data bank containing information on pollutant discharges from all types of area and point sources. Data, generated primarily by state agencies, are entered in the NEDS computerized data base for general use in what is basically a "bottom-up" inventory. The quality of the data is a factor of the resources available to the states to collect information from the operators of facilities that emit pollution. Although input data are screened to some extent, the accuracy of the various data base elements has not been well defined. Some users of NEDS believe that certain components (e.g., as utility and iron and steel plants) are well documented. Data for other more fragmented categories, however, many of which are associated with small sources such as foundries and industrial boilers, are not well documented. Hence, it appears that the state agencies have never supplied NEDS with sufficiently detailed information for an inventory of uniform accuracy.

Since NEDS has served many needs over the years, any inaccuracies that may exist in some categories do not appear to have caused serious problems. Nevertheless, in the past several years the need for better and more comprehensive regional and local inventories has been considered in several quarters. The data base for industrial and commercial boilers, for example, is thought to be inadequate in light of the pollution problem they are now believed to present. Efforts by the Department of Energy

(DOE) to conduct a Major Fuel Burning Installation (MFBI) survey intended to provide a useful perspective for major facilities met with limited success, and plans for a followup survey were cancelled as an economy measure. Studies of acid rain also have generated pressure for more accurate inventory data for assessment of the role local sources play in regional pollution. Currently, several groups are searching for better answers to this problem of international concern.

The need for a comprehensive independently derived inventory was considered early in an ongoing reassessment of NO_x emissions reduction R&D programs being conducted by the Industrial Environmental Research Laboratory in Research Triangle Park (IERL-RTP). After review of the proposed concept, the feasibility study of a current project was initiated to investigate the feasibility of developing a comprehensive NO_x emissions inventory, based on a "top down" assessment not dependent on either a survey or fuel consumption data or on inventories based on surveys. Its objective was to develop an independent inventory based on published sources of data (other than the NEDS data base) to provide a second source of information, especially in the industrial/commercial areas, for which the existing data base may be considered inadequate.

2.2 THE GENERAL APPROACH

The approach as it was conceived and applied to this project is unique in that it began with an analysis of all consumption of major fossil fuels for the purpose of:

- identifying all important fuel-usage categories, and
- identifying the important kinds of combustion equipment used within each category.

This approach to the analysis of major fossil fuel consumption permitted the use of an energy accounting methodology to quantify the degree to which the inventoried sources in individual consuming sectors are complete and representative of the total sector population. Also, the approach was designed to define all major blocks of fuel use in fuel-type-application categories without becoming involved with unnecessary detail. Still, it was intended that the coverage would be comprehensive in both the identification of those categories that are of importance and complete in the analysis of the important types of hardware employed in each category. The objective was to show that a relatively simple inventory method could be used to show the combustion sources of real significance to NO_x emissions.

As a first step, available data on fuel consumption were broken down into the major usage categories (i.e., residential, commercial, transportation, electric utility, and industrial) for all the fossil fuels shown in Table 2-1.* The first subdivisions for analysis and the amounts of fuel represented by each sector/fuel type category are shown in Table 2-2.* These categories account for almost 95 percent of the total of 67.7 x 1015 Btu of fossil fuel burned in 1979. The balance is used either in applications

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* U.S. Department of Energy. State Energy Data Reports. DOE-EIA-0214(79), September 1981.

TABLE 2-1. FOSSIL FUEL CONSUMPTION FOR THE UNITED STATES IN 1979[1]
(10^{12} Btu)

	Residential	Commercial	Transportation	Electric utility	Industrial	Total
Natural gas	5,055	2,836	611	3,609	8,549	20,660
Liquified petroleum gas (LPG)	456	81	8	0	1,594	2,139
Distillate oil	1,600	574	2,858	271	1,736	7,039
Kerosene	242	0	0	0	147	389
Residual oil	0	511	1,242	3,060	1,674	6,487
Coal	82	129	Nil	11,263	3,702	15,176
Motor gasoline	0	110	13,221	0	156	13,487
Jet fuel	0	0	2,186	18	0	2,204
Petroleum coke	0	0	0	8	0	8
Aviation gasoline	0	0	70	0	0	70
Other petroleum products	0	1,153[a]	193[b]	0	3,955[c]	5,301
Total fossil fuel consumption	7,435	5,394	20,389	18,229	21,513	72,960
Total fossil fuel - combustion only	7,435	4,241	20,196	18,229	17,558	67,659

[a] Asphalt 1142, Road Oil 11.

[b] Lubricants.

[c] Lubricants 204, and Misc. Petroleum Products 3751 (mostly chemical feedstocks).

TABLE 2-2. FOSSIL FUEL BURNING BY CONSUMING SECTOR[1]

Sector/fuel	Quantity, 10^{12} Btu
Residential	
Gas (natural and LPG)	5,511
Oil (distillate and kerosene)	1,842
Commercial	
Gas (natural and LPG)	2,917
Distillate oil	574
Residual oil	511
Transportation	
Gas (natural and LPG)	619
Distillate oil	2,858
Motor gasoline	13,221
Electric utility	
Natural gas	3,609
Light oil (distillate and jet fuel)	288
Residual oil	3,060
Coal	11,263
Industrial	
Gas (natural and LPG)	10,143
Oil (distillate and kerosene)	1,883
Residual oil	1,674
Coal	3,702
	Total 63,675

too small to be of concern or in nonstationary applications that do not directly contribute to pollution of ambient air over terrestrial areas (e.g., aircraft and seagoing ships).

Fuel consumption data are available for individual states of the United States for each of the sector/fuel categories shown in Table 2-2; however, no data for individual counties are in available energy publications. Fortunately, fuel consumption and pollution emission studies (References 2 through 11 are examples) in recent years have produced the data needed to derive consumption estimates for individual counties and to divide the categories in Table 2-2 further according to usage. In addition, these studies have generated the kinds of information needed to identify and characterize the major types of combustion equipment used in each fuel-type-application category. This key information is essential to the generation of meaningful emission estimation. The element important in this demonstration study was to show that the important information could be obtained and applied to the development of a geographically detailed NO_x emissions estimate without becoming immobilized by the profusion of excess detail present in the data bases to be used.

Figure 2-1 shows the relationships between fuel consumption, consuming sector, fuel type, application, and type of air pollution source. The approach to the analysis of the five categories is described in the following subsections.

2.2.1 Residential and Commercial Sectors

Fuel use for the residential and commercial sectors was assumed to be proportional to the population, and sector fuel

	CONSUMING SECTOR (QUADS)	FUEL TYPE (QUADS)	EQUIPMENT TYPES	SOURCE TYPES
FOSSIL FUEL TO CONSUMING SECTORS (63.7 x 10^{15} Btu)	RESIDENTIAL (7.4)	GAS†(5.5)* D.O.†(1.8)	SPACE HEATERS WATER HEATERS COOKING STOVES OTHER	AREA SOURCES
	COMMERCIAL (4.0)	GAS (2.9) D.O. (0.6) R.O.† (0.5)	SPACE HEATERS WATER HEATERS COOKING STOVES OTHER	AREA SOURCES
	TRANSPORTATION (16.7)	GAS (0.6) D.O. (2.9) GASOLINE (13.2)	MOTOR VEHICLES PIPELINE COMPRESSORS AND PUMPS	AREA SOURCES
	ELECTRIC UTILITY (18.2)	GAS (3.6)* D.O. (0.3) COAL (11.3) R.O. (3.1)	STEAM BOILERS GAS TURBINES STATIONARY I C[a] ENGINES	POINT SOURCES
	INDUSTRIAL (17.4)	GAS (10.1) D.O. (1.9) R.O. (1.7) COAL (3.7)	STEAM BOILERS DIRECT-FIRED PROCESSES STATIONARY I C ENGINES GAS TURBINES OTHER	POINT SOURCES AND AREA SOURCES

*DIFFERENCE BETWEEN TOTAL AND SUM OF VALUES FOR INDIVIDUAL FUELS DUE TO ROUNDING.

† GAS = NATURAL GAS
D.O. = DISTILLATE OIL
RO = RESIDUAL OIL

[a] IC = INTERNAL COMBUSTION

Figure 2-1. Breakdown of total fuel consumption on a national basis.

consumption for individual states was prorated to individual counties. The derived county fuel use data were converted to NO_x emissions using emission factors developed from analysis of fuel burning practices in the sector. These sectors were treated as area sources and considered to be distributed uniformly for each county.

2.2.2 Transportation Sector

The transportation sector includes liquid fuels used in motor vehicles and natural gas used in pipeline transport of fuel. The consumption of liquid transportation fuels was assumed to be proportional to the number of registered motor vehicles in individual counties. Emission factors were derived by analysis of information on emissions from various types of motor vehicles, and area NO_x emissions were estimated by county. The combustors involved in pipeline transport are a part of a larger population of stationary internal combustion (IC) engines and gas turbines. As discussed later, they have been given only partial analysis.

2.2.3 Electric Utility

Fuel consumption by electric utilities is well documented by both states and counties as far as type and amount of fuel used, types and location of combustors, etc., are concerned. Hence, power plants in the study area were not subjected to the same analysis used for other sectors. Instead, NO_x emission estimates were obtained directly from the National Emissions Data System and included in the results of the analysis for comparison purposes.

2.2.4 Industrial Sector

In the industrial sector, fuel is used in major direct-fired processes, in large industrial boilers, and in a wide variety of smaller combustors, including small boilers, stationary IC engines, gas turbines, ovens, and dryers. Prior to this study, this sector has never received what might be called a systematic investigation for the comprehensive identification of major combustion sources.

In summary, it appears that all major sectors except the industrial sector can be analyzed without unreasonable effort to develop combustion source inventories that are translatable into emission estimates. The more complex approach required for the industrial sector is discussed in Section 3.

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SECTION 3

APPROACH TO INDUSTRIAL COMBUSTION SOURCE ASSESSMENT

3.1 INTRODUCTION

The approach to analysis of industrial sector NO_x emissions began with a systematic evaluation of specific blocks of fuel burning that make up the total for industrial combustion. The methodology was analogous to the previously discussed approach for other fuel-consuming sectors in that it accounts for all fuel use in some manner. A further similarity was that upon completion of the analysis, all industrial fuel consumption for individual counties was accounted for either in specifically located major point sources or as area sources.

Figure 3-1 presents an overview of all the 1979 industrial fuel consumption of 24.7×10^{15} Btu that clarifies the scope of the analysis. The data show that total consumption includes electricity (7.0×10^{15} Btu), which is not included in the investigation. The fuels considered in the study, which totaled 17.7×10^{15} Btu, consisted of purchased fuels (10.6×10^{15} Btu) and nonpurchased fuels (7.1×10^{15} Btu).* The latter category

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* It should be noted that the total industrial fuel consumption shown in Figure 3-1 (17.7×10^{15} Btu) does not exactly correspond with that shown in Figure 2-1 (17.4×10^{15} Btu). The data shown in Figure 3-1 are approximations based on data from various sources and represent different years in the 1977-1980 period. These data are used in lieu of more consistent information.

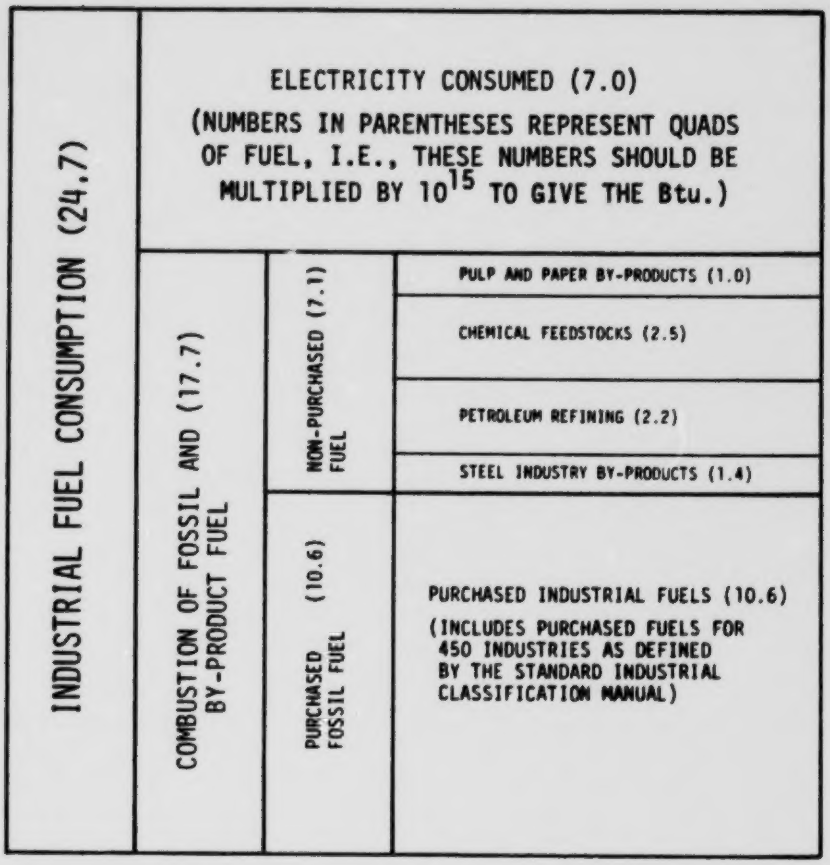
INDUSTRIAL FUEL CONSUMPTION (24.7)
ELECTRICITY CONSUMED (7.0)
(NUMBERS IN PARENTHESES REPRESENT QUADS OF FUEL, I.E., THESE NUMBERS SHOULD BE MULTIPLIED BY 10^15 TO GIVE THE Btu.)
COMBUSTION OF FOSSIL AND BY-PRODUCT FUEL (17.7)
NON-PURCHASED FUEL (7.1)
PULP AND PAPER BY-PRODUCTS (1.0)
CHEMICAL FEEDSTOCKS (2.5)
PETROLEUM REFINING (2.2)
STEEL INDUSTRY BY-PRODUCTS (1.4)
PURCHASED FOSSIL FUEL (10.6)
PURCHASED INDUSTRIAL FUELS (10.6)
(INCLUDES PURCHASED FUELS FOR 450 INDUSTRIES AS DEFINED BY THE STANDARD INDUSTRIAL CLASSIFICATION MANUAL)

Figure 3-1. Breakdown of total industrial fuel consumption in 150-county study area.

includes chemical feedstocks that are not of interest because they do not involve combustion; coal used for coke in steelmaking; and byproduct fuels from petroleum refining and pulp and paper manufacturing.

These major blocks of fuel combustion were estimated from open literature sources. The largest block of fuel included 10.6 x 10^{15} Btu of fuel burned in manufacturing establishments (as defined by the 1977 Census of Manufacturers). From the standpoint of NO_x emissions, this segment of the total industrial energy consumption is the most difficult to define. The Census of Manufacturers, which is conducted at 5-year intervals, provides considerable information on the use of purchased fuels. The summary of Census data in Table 3-1 provides additional detail for the 13.6 x 10^{15} Btu of purchased fuel use by fuel type and Standard Industrial Classification (SIC) categories. Census data were combined with data from the open literature[1-4] for nonpurchased fuels to provide a reasonable picture of overall industrial consumption patterns. The data cannot be translated into combustion equipment and NO_x emission inventories, however, without further definition of the fuel burning hardware and NO_x emission characteristics for those usage categories associated with purchased fuels.

3.2 CLASSIFICATION OF INDUSTRIAL NO_x COMBUSTION SOURCES

Further definition of the combustion hardware was accomplished by systematic analyses that divided all industrial fuel

TABLE 3-1. INDUSTRIAL ENERGY CONSUMPTION - 1977 [1-4]
(10^{12} Btu)

	Industry	Electricity[a]	Distillate oil	Residual oil	Coal	Coke & Breeze	Natural gas	Other[b,c]	Sub-total	Non-purchased fuels	Total
20	Food and kindred	420.4	75.3	120.4	88.7	1.4	436.7	93.3 (82.4)	1236.2	-	1236.2
21	Tobacco	13.2	1.6	5.5	7.0[d]	-	2.4	-	29.7	-	29.7
22	Textiles	289.9	29.0	73.2	31.6	-	75.8	35.4 (33.5)	534.9	-	534.9
23	Apparel	69.5	4.5	4.2	1.8	-	15.6	16.9 (2.1)	112.5	-	112.5
24	Lumber and wood	169.6	33.6	15.3	17.9[d]	-	65.5	40.3 (40.3)	342.2	-	342.2
25	Furniture	43.7	5.3	2.8	2.9	-	18.4	9.1 (8.6)	82.2	-	82.2
26	Paper	468.1	33.4	472.8	226.9	-	358.4	64.8 (61.5)	1624.4	953[e]	2577.4
27	Printing.	110.8	5.9	2.8	12.0[d]	-	29.1	6.5 (6.5)	167.1	-	167.1
28	Chemicals	1565.8	118.9	286.2	342.1	59.0[f,g]	1519.6	143.9 (143.9)	4035.0	2479[h]	6514.0
29	Petroleum	316.7	22.4	61.0	4.8	-	1076.2	12.9 (12.9)	1494.0	2176[i]	3670.0
30	Rubber	237.0	18.5	47.2	23.9	-	73.0	32.7 (28.1)	432.3	-	432.3
31	Leather	15.1	2.1	5.3	1.2	-	5.6	4.0 (3.8)	33.3	-	33.3
32	Stone, clay, glass	323.7	80.9	82.2	344.4	9.7	536.1	93.3 (75.8)	1470.3	-	1470.3
33	Primary metals	1656.2	72.5	259.6	135.4	496.2[j]	927.3	110.2 (108.0)	3657.4	1456.1[g]	5113.5
34	Fabricated metals	277.3	27.2	22.2	10.8	1.6	188.7	54.7 (50.1)	582.5	-	582.5
35	Machinery	298.8	20.0	21.6	18.5	2.8	131.0	48.6 (44.2)	541.3	-	541.3
36	Electronics	262.2	16.1	15.2	14.3	0.3	86.4	31.8 (29.2)	426.3	-	426.3
37	Transportation	325.3	16.6	35.2	48.3	5.4	140.9	37.8 (36.2)	609.5	-	609.5
38	Instruments	58.2	3.4	9.3	25.8[d]	-	18.1	2.9 (2.9)	117.7	-	117.7
39	Miscellaneous	43.4	4.4	5.3	7.4[d]	-	15.1	2.8 (2.8)	78.4	-	78.4
	Total	6964.9	591.6	1547.3	1365.7	576.4	5719.9	841.9	17607.6	7064.1	24671.7

Note: All base numbers are from the Bureau of Census Annual Survey of Manufacturers, 1977, Part 1. Conversion factors are as follows: Coal - 26.194E6 Btu/ton; Coke - 25.993E6 Btu/ton; Residual oil - 6.285E6 Btu/bbl; Distillate oil - 5.824E6 Btu/bbl; Natural gas - 1024 Btu/ft^3; Other - 478E3 Btu/$.

[a] Electric quantities were converted from kWh to Btu by the factor 10500 Btu/kWh.

[b] Differences in reported fuels and the total Census quantities were adjusted in the "other" fuels column.

[c] Items in parentheses represent the total as indicated by Census Data.

[d] Figure not reported by the Census; derived by difference.

[e] Byproduct fuel as reported by API (Reference 3).

[f] Actual reported coking coal use was 85 x 10^{12} Btu (Reference 4), assuming 70 percent conversion the coke consumption would be 59.5 x 10^{12} Btu.

[g] Consists of 500.7 coal; 955.4 coke and breeze.

[h] Feedstock as reported by Shell (Reference 4).

[i] Byproduct as reported by the Bureau of Census (Reference 1).

[j] Estimated by PEDCo, based on 1978 DOE data (Reference 2).

burning into that burned in identifiable "major point sources"[*] and that consumed in area sources.[†] Many major point sources are well documented in the literature. Several of these (which were investigated in an earlier phase of this study to test the feasibility of the methodology) are listed in Table 3-1. Because no previous study had defined the total population of point sources, the completeness of any given listing of sources (e.g., that used in the earlier feasibility study) was not certain. Hence, a search based on all the "industries" defined for the manufacturing sector in the Census of Manufacturers was undertaken as an important part of the industrial fuel analysis.

3.2.1 Identification of Major Direct-Fired Point Sources

As a first step, about 450 SIC industries represented by 4-digit codes in the Census data bank were screened to eliminate all of those whose total fuel use was less than 100 x 10^9 Btu/establishment/year.[5] This limit is believed to be sufficiently low to preclude the possibility of the existence of any major direct-fired point source (as defined for the study) in the industries with lower average annual fuel consumptions. This screening process reduced the total number of industries for further investigation from 450 to the 114 shown in Table 3-2.

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[*] After a source analysis was made of fuel burning industrial combustors, it was decided that all sources with estimated annual fuel consumption of 100 x 10^9 Btu would be considered major point sources. This limit proved to be impractical for industrial boilers, and a lower size limit of 250 x 10^6 Btu/h was used.

[†] This represents a classic approach consistent with the NEDS treatment. It allows direct comparisons to be made even though an independent approach was used.

TABLE 3-2. STANDARD INDUSTRIAL CLASSIFICATION CODES WITH CONSUMPTION OF FOSSIL FUELS GREATER THAN 100 x 10^9 Btu PER YEAR[5]

	Average 1977 consumption per establishment, 10^9 Btu	
	All establishments	Establishments with 20 or more employees
SIC 20 - Food and kindred products		
2023 - Condensed and evaporated milk	88.7	159.4
2032 - Canned specialties	84.7	195.4
2034 - Dehydrated fruits, vegetables, and soups	72.8	154.0
2037 - Frozen fruits and vegetables	104.2	140.4
2043 - Cereal breakfast foods	170.8	234.2
2046 - Wet corn milling	2,023.0	2,922.2
2061 - Raw cane sugar	189.2	223.6
2062 - Cane sugar refining	802.5	1,188.8
2063 - Beet sugar	1,294.7	1,419.2
2066 - Chocolate and cocoa products	64.2	133.3
2075 - Soybean oil mills	334.7	465.5
2076 - Vegetable oil mills, N.E.C.[a]	47.6	105.2
2077 - Animal and marine fats and oils	54.2	134.8
2079 - Shortening and cooking oils	229.3	312.5
2082 - Malt beverages	329.7	474.7
2083 - Malt	210.0	311.1
2085 - Distilled liquor, except brandy	139.4	188.3
SIC 21 - Tobacco products		
2111 - Cigarettes	750.0	807.6
SIC 22 - Textile mill products		
2211 - Weaving mills, cotton	66.8	109.3
2261 - Finishing plants, cotton	116.6	260.6
2262 - Finishing plants, synthetics	148.0	223.2
2272 - Tufted carpets and rugs	61.6	110.3
2296 - Tire cord and fabric	125.0	125.0

(continued)

[illegible] (continued)

	[illegible]	
	[illegible]	[illegible]
SIC 24 — Lumber and wood products		
2436 — Softwood veneer and plywood	[illegible]	[illegible]
2492 — Particleboard	[illegible]	[illegible]
SIC 26 — Paper and allied products		
2611 — Pulp mills	[illegible]	[illegible]
2621 — Paper mills, except building paper	[illegible]	[illegible]
2631 — Paperboard mills	[illegible]	[illegible]
2661 — Building paper and board mills	[illegible]	[illegible]
2646 — Pressed and molded pulp goods	[illegible]	[illegible]
SIC 28 — Chemicals and allied products		
2812 - Alkalies and chlorine	[illegible]	[illegible]
2813 - Industrial gases	[illegible]	[illegible]
2816 - Inorganic pigments	[illegible]	[illegible]
2819 - Industrial inorganic chemicals, N.E.C.	[illegible]	[illegible]
2821 - Plastic materials and resins	[illegible]	[illegible]
2822 - Synthetic rubber	[illegible]	[illegible]
2823 - Cellulosic manmade fibers	[illegible]	[illegible]
2824 - Organic fibers, noncellulosic	[illegible]	[illegible]
2833 - Medicinals and botanicals	[illegible]	[illegible]
2834 - Pharmaceutical preparations	[illegible]	[illegible]
2841 - Soap and other detergents	[illegible]	[illegible]
2843 - Surface active agents	[illegible]	[illegible]
2861 - Gum and wood chemicals	[illegible]	[illegible]
2865 - Cyclic crudes and intermediates	[illegible]	[illegible]
2869 - Industrial organic chemicals, N.E.C.	[illegible]	[illegible]
2873 - Nitrogenous fertilizers	[illegible]	[illegible]
2874 - Phosphatic fertilizers	1,538.1	[illegible]
2879 - Agricultural chemicals, N.E.C.	583.5	[illegible]
2892 - Explosives	87.4	[illegible]
2895 - Carbon black	188.7	[illegible]
2899 - Chemical preparations, N.E.C.	877.4	877.4
	32.4	130.8

(continued)

TABLE 3-2 (continued)

	Average 1977 consumption per establishment, 10^9 Btu	
	All establishments	Establishments with 20 or more employees
SIC 29 - Petroleum refining and related industries		
2911 - Petroleum refining	3,225.5	4,034.7
2951 - Paving mixtures and blocks	32.7	203.0
2952 - Asphalt felts and coatings	103.6	173.7
2999 - Petroleum and coal products, N.E.C.	104.2	317.3
SIC 30 - Rubber and miscellaneous plastic products		
3011 - Tires and inner tubes	324.0	514.2
3041 - Rubber and plastic hose and belting	76.7	108.7
SIC 32 - Stone, clay, glass, and concrete products		
3211 - Flat glass	893.5	1,731.2
3221 - Glass containers	1,022.2	1,038.7
3229 - Pressed and blown glass, N.E.C.	157.5	481.6
3241 - Cement, hydraulic	2,087.0	2,621.8
3251 - Brick and structural clay tile	190.3	255.7
3253 - Ceramic wall and floor tile	79.7	131.2
3255 - Clay refractories	118.5	190.3
3259 - Structural clay products, N.E.C.	155.7	308.7
3261 - Vitreous plumbing fixtures	115.7	213.1
3262 - Vitreous china food utensils	100.0	200.0
3263 - Fine earthenware food utensils	82.6	111.7
3274 - Lime	1,014.8	1,514.2
3275 - Gypsum products	339.8	537.0
3292 - Asbestos products	61.7	100.0
3295 - Minerals, ground or treated	64.5	199.3
3296 - Mineral wool	305.2	518.8
3297 - Nonclay refractories	145.8	240.9
3299 - Nonmetallic mineral products, N.E.C.	10.9	108.5

(continued)

TABLE 3-2 (continued)

	Average 1977 consumption per establishment, 10^9 Btu	
	All establishments	Establishments with 20 or more employees
SIC 33 - Primary metal industries		
3312 - Blast furnaces and steel mills	2,696.4	5,436.0
3316 - Cold finishing of steel shapes	94.1	155.3
3317 - Steel pipe and tubes	98.3	124.6
3321 - Gray iron foundries	98.6	142.1
3322 - Malleable iron foundries	178.7	222.6
3325 - Steel foundries, N.E.C.	73.0	103.0
3331 - Primary copper	2,211.1	2,211.1
3332 - Primary lead	1,671.4	1,671.4
3333 - Primary zinc	2,700.0	3,085.7
3334 - Primary aluminum	3,334.3	3,334.3
3339 - Primary nonferrous metals, N.E.C.	224.7	734.6
3341 - Secondary nonferrous metals	74.3	171.0
3351 - Copper rolling and drawing	129.2	182.8
3353 - Aluminum sheet, plate, and foil	1,096.2	1,291.1
3354 - Aluminum extruded products	89.1	117.8
3355 - Aluminum rolling and drawing, N.E.C.	290.9	426.6
3356 - Nonferrous rolling and drawing, N.E.C.	51.7	103.4
SIC 34 - Fabricated metal products, except machinery and transportation equipment		
3431 - Enameled iron and metal sanitary ware	51.4	140.5
3462 - Iron and steel forgings	121.2	187.8
3463 - Nonferrous forgings	104.2	158.0
3482 - Small arms ammunition	47.6	193.7
3483 - Ammunitions, except small arms, N.E.C.	72.8	120.4
3489 - Ordance and accessories, N.E.C.	49.4	107.3

(continued)

TABLE 3-2 (continued)

	Average 1977 consumption per establishment, 10^9 Btu	
	All establishments	Establishments with 20 or more employees
SIC 35 - Machinery, except electrical		
3511 - Turbines and turbine generator sets	78.5	173.6
3519 - Internal combustion engines, N.E.C.	71.1	125.9
3562 - Ball and roller bearings	79.8	114.4
3599 - Machinery, except electrical, N.E.C.	101.9	183.3
SIC 36 - Electrical and electronic machinery, etc.		
3624 - Carbon and graphite products	133.7	206.2
3631 - Household cooking equipment	53.1	204.0
3632 - Household refrigerators and freezers	233.3	392.0
3633 - Household laundry equipment	200.0	258.3
3639 - Household appliances, N.E.C.	66.2	132.5
SIC 37 - Transportation equipment		
3711 - Motor vehicles and car bodies	283.8	768.0
3721 - Aricraft	103.4	245.9
3764 - Space propulsion units and parts	119.2	134.7
3743 - Railroad equipment	63.6	108.4
3795 - Tanks and tank components	120.8	161.1
SIC 38 - Measuring, analyzing, etc.		
3861 - Photographic equipment and supplies	43.7	129.2
SIC 39 - Miscellaneous manufacturing industries		
3996 - Hard surface floor coverings	147.6	238.4

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[a] N.E.C. = not elsewhere classified.

The remaining 114 SIC industries were then reviewed to identify any major direct-fired combustion sources. Some industries have a high overall energy consumption but are not believed to comprise a major direct-fired point source. This situation resulted in the elimination of these industries if one of the following was true:

1) If the industries were known to rely heavily on steam as opposed to direct-fired processes. (These boiler sources are evaluated separately from direct-fired sources.)

2) If the industries were associated with the manufacture of equipment (such as machinery and motor vehicles), where onsite foundries would contribute to high fuel consumption. (Foundries were covered categorically rather than by industry.)

3) If the industries have high space heat requirements (such as those involved with assembly line work).

Although most of the industries with high overall energy consumption or average facility consumption below 100 x 10^9 Btu/yr, appeared unlikely to involve major direct-fired point sources that have not been identified, additional work could reveal new sources or indicate additional applications of some that have been identified. For example, reheat furnaces for nonferrous metals may be used in industries other than SIC 3353 - Aluminum Plate, Sheet, and Foil. Further investigation along these lines was not possible in the present study, but based on the above three criteria, it is believed that any error that may have been introduced would not significantly change the overall findings.

The final screening of 114 SIC industries produced a list of major point sources believed to include all those that must be considered for a reasonably comprehensive inventory of sources. This list, which consists of 73 major point source processes associated with 28 facility types, is presented in Table 3-3, along with NO_x emission factors[8-12] derived for each process and its associated direct-fired equipment.

3.2.2 Industrial Boilers

Industrial boilers were analyzed by use of existing data bases which included data from the EPA's National Emissions Data Systems (NEDS), DOE's Major Fuel Burning Installation (MFBI) survey, PEDCo's three-state boiler study conducted for EPA, and in-house data on specific installations that PEDCo visited during the preparation of coal conversion reports for DOE. In essence, this approach involved the development of the best boiler population description for the study area that was possible from data bases known to be of limited quality. Past studies have demonstrated that no better data will be available until an accurate national survey is made.

Past experience with boilers also indicated the impracticality of attempting to locate all boilers firing over 100 x 10^9 Btu/yr within the study area. Thus, a lower limit of 250 x 10^6 Btu/h was used, even though this was about 10 times greater than the standard for major point-source processes.

TABLE 3-3. LIST OF MAJOR POINT SOURCE INDUSTRIES AND SELECTED NO_x EMISSION FACTORS

Industry	Plant or facility	Process	Equipment	NO_x emission factors
Petroleum refining	Petroleum refinery[a]	Atmospheric distillation[a]	Process heater	Oil: 55 lb/10^3 gal^9 Gas: 140 lb/10^6 ft^3 ^{9}
		Vacuum distillation[a]	Process heater	Oil: 55 lb/10^3 gal^9 Gas: 140 lb/10^6 ft^3 ^{9}
		Thermal operation[a]	Process heater	Oil: 55 lb/10^3 gal^9 Gas: 140 lb/10^6 ft^3 ^{9}
		Catalytic cracking[a]	Process heater	Oil: 55 lb/10^3 gal^9 Gas: 140 lb/10^6 ft^3 ^{9}
		Catalytic reforming[a]	Process heater	Oil: 55 lb/10^3 gal^9 Gas: 140 lb/10^6 ft^3 ^{9}
		Hydrocracking[a]	Process heater	Oil: 55 lb/10^3 gal^9 Gas: 140 lb/10^6 ft^3 ^{9}
		Hydrorefining[a]	Process heater	Oil: 55 lb/10^3 gal^9 Gas: 140 lb/10^6 ft^3 ^{9}
		Alkylation[a]	Process heater	Oil: 55 lb/10^3 gal^9 Gas: 140 lb/10^6 ft^3 ^{9}
		Aromatic manufacturing[a]	Process heater	Oil: 55 lb/10^3 gal^9 Gas: 140 lb/10^6 ft^3 ^{9}
Petrochemicals	Petrochemical plants[a]	Ammonia (steam hydrocarbon reforming)[a]	Tubular furnace	5.8 lb/ton[9]
		BTX	Tubular preheater	b
		Butadiene (Naphtha cracking)	Tubular preheater	b
		Carbon black (Oil furnace process)	Oil reactor	0.56 lb/ton[9]
		Ethanol (Naphtha cracking)	Tubular preheater	b
		Ethylene/propylene (Naptha cracking	Tubular preheater	b
		Methanol (Low pressure)	Reforming tubestill furnace	b
Industrial organic chemicals	Industrial inorganic chemical plants	Dimethyl terephalate (Dynamit Nobel)	Tubular preheater	b
		Ethylenebenzene/styrene (Monsanto)	Superheater	b
		Borax (Drying)	Tray or spray dryer	0.085 lb/10^6 Btu[9]
		Lithium hydroxide (Calcination)	Rotary kiln	b
		Sodium carbonate (Monohydrate)	Rotary kiln	b
Phosphate rock and basic fertilizer	Phosphate rock and basic fertilizer plants[a]	Potash (calcination)	Rotary kiln	b
		Potash (drying)	Rotary dryer	b
		Potash (leaching)	Rotary dryer	b
		Sodium phosphate (fusion/calcination)[a]	Rotary kiln	0.033 lb/10^6 Btu[9]
		Sodium phosphate (crystallization/drying)[a]	Spray dryer	0.085 lb/10^6 Btu[9]
Pulp and paper	Pulp mills[a]	Kraft[a]	Lime kiln	1 lb/ton pulp[9] or 3 lb/ton lime[c]
Gypsum	Gypsum plants[a]	Drying/calcination[a]	Dryer/calciner	b

(continued)

TABLE 3-3 (continued)

Industry	Plant or facility	Process	Equipment	NO_x emission factors
Lime	Lime plants[a]	Calcination[a]	Lime kilns	3 lb/ton[9]
Clay products	Brick and tile plants[a]	Firing[a]	Tunnel/periodic kiln	0.23 lb/ton[9]
	Lightweight aggregate plants[a]	Expansion[a]	Rotary kiln	3 lb/ton[b]
Cement	Cement plants[a]	Wet and dry[a]	Cement kiln (rotary)	2.6 lb/ton[11]
Glass	Container glass plants[a]	Melting[a]	Melting furnace (reverb. type)	6.2 lb/ton[9]
	Flat glass plants[a]	Melting[a]	Melting furnace	8.0 lb/ton[9]
	Pressed and blown glass plants[a]	Melting[a]	Melting furnace	8.5 lb/ton[9]
Diatomite	Diatomite plants	Drying/calcination	Calciner	c
Mineral wool	Mineral wool plants[a]	Melting[a]	Cupola	c
Iron and steel	Integrated plants[a]	Sintering[a]	Sinter plant	1.8 lb/ton sinter[12]
		Coking[a]	Coke oven	1.89 lb/ton coke[12]
		Steelmaking[a]	Blast furnace stoves	0.34 lb/ton pig iron[12]
			Basic oxygen furnace	a
			Electric furnace	0.01 lb/ton steel[12]
			Open hearth	4.5 lb/ton steel[12]
		Melting[a]	Reheating furnace	1.1 lb/ton steel[12]
		Slabbing/blooming[a]	Soaking pits	0.8 lb/ton steel[12]
			Continuous casting	c
	Mini and midi plants	Melting[a]	Reheating furnace	1.1 lb/ton steel[12]
		Slabbing/blooming[a]	Soaking pits	0.8 lb/ton steel[12]
	Iron foundries	Melting[a]	Cupola	0.11 lb/ton[9]
Primary copper	Copper smelters and refineries	Smelting	Reverberatory furnace	0.9 lb/ton[9]
		Roasting	Roaster	c
		Cathode melting	Melter	c
		Arsenic oxide (roasting)	Roaster	c
Primary lead	Lead smelters and refineries	Sintering	Sinter plant	c
		Smelting	Blast furnace	c
		Softening	Softening furnace	c
		Desilverizing	Desilverizing kettle	c
		Debismuthing	Debismuthing kettle	c
		Refining	Refining kettle	c
Primary zinc	Zinc smelters and refineries	Roasting	Roaster	c
		Sintering	Sinter plants	c
		Electrothermic reduction	Electrothermic retort	c
		Secondary materials preparation	Dryer	c

(continued)

TABLE 3-3 (continued)

Industry	Plant or facility	Process	Equipment	NO_x emission factors
Primary titanium	Titanium smelters	Chlorination Reduction Leaching Drying	Chlorinator Batch reactor Acid leach reactor Drying	Negligible c c c
Primary tin	Tin smelter	Smelting	Blast furnace	c
Primary magnesium	Magnesium smelter	Calcination	Reverberatory furnace	0.04 lb/10^6 Btu[9]
Secondary nonferrous metals	Aluminum smelter[a]	Sweating[a] Smelting[a]	Sweating furnace Reverberatory furnace	0.15 lb/10^6 Btu[9] 0.12 lb/10^6 Btu[9]
	Copper smelter and refineries[a]	Sweating[a] Smelting[a]	Sweating furnace Blast furnace/ Reverberatory furnace	0.1 lb/ton[9] 0.56 lb/ton[9] 0.96 lb/10^6 Btu[9]
		Refining[a]	Reverberatory furnace	0.96 lb/10^6 Btu[9]
	Lead smelter[a]	Smelting[a]	Blast furnace or Reverberatory furnace	0.56 lb/ton[9] 0.38 lb/10^6 Btu[9]
Aluminum fabrication	Sheet, plate and foil plants[a]	Melting[a] Heat treating[a]	Reverberatory furnace Heat treating furnace	c c

[a] Plants/processes in the 150-county study area.

[b] Used the lime kiln emission factor based on similarities in equipment type, furnace temperature, and predominant fuel.

[c] See graphs in Figures 3-3 and 3-4.[9]

3.2.3 Other Industrial Combustion Sources

After the identification of all major point sources in a given area, the total major point source fuel consumption was estimated and combined with boiler fuel consumption. The "residual" industrial consumption was determined for each state by subtracting the boiler fuel and point source consumption from the total for the state reported in the DOE "State Energy Data Report." Normally this "residual" would be converted to NO_x emissions by use of an average $NO_x/10^6$ Btu emission factor and treated as area source emissions to be distributed to individual counties on a population basis. For reasons unique to this study, the treatment of NO_x emissions (to be discussed later) was different.

Stationary gas turbines and stationary IC engines have been identified as important contributors to the industrial residual NO_x emissions. Gas turbines used in pipeline transport of natural gas are the most important of these sources within the scope of the study.* An estimated 10,000 to 15,000 units, including IC engines and gas turbines, are used for pipeline transport of fuel. The average unit size is such that many appear to consume more than the 100×10^9 Btu per year that is needed to qualify them as major point sources. Because it was impractical to deal with a population of this size in the current study, the investigation was limited to evaluation of the general impact of gas turbines transporting natural gas in the study area. Calculations and evaluation of total NO_x emissions were based on miles of pipeline in the study area and an average emission factor. Results of this assessment are reported in Section 4.

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* Utility turbines, not within the scope of the study, are about on par with those used for pipelines as far as potential emissions are concerned.

3.3 APPLICATION OF THE METHODOLOGY TO THE STUDY AREA

The final test of the methodology was its application to the development of combustion source and NO_x inventories for the 150 counties in the chosen study area. The steps in this application were as follows:

1) Identification and location of major point sources
2) Development of fuel consumption estimates for major point sources
3) Development of fuel consumption estimates for area sources
4) Determination of emission factor and calculation of emissions for point and area sources

3.3.1 Identification and Location of Major Point Sources

Up-to-date trade association listings were used to identify and locate individual plants within the study area for most major industrial point sources. Where such information was not available (e.g., for foundries, glass plants, and brick and tile plants), estimates were made from market data purchased from Economic Information Systems, Inc. Section 4 contains a breakdown of the number of the plants located in the study area, by industry and plant type. Sources of information used for individual sources are given in Appendix B.

3.3.2 Fuel Consumption Estimated for Point Sources

Methodologies for estimating fuel consumption were developed for each major industry and process in the study area. The general methodology involved the use of documented unit energy consumption factors and production data to establish a total energy use estimate for fossil fuels at an individual plant. This methodology is illustrated in Figure 3-2. Brief descriptions of the methodologies developed for each direct-fired process, as well as industrial boilers, are presented in Appendix B.

Fuel consumption estimates for large industrial boilers were taken from NEDS and MFBI.

3.3.3 Fuel Consumption for Area Sources

The methodology for estimating fuel consumption by area sources covered the residential, commercial, and transportation sectors.

Residential and commercial energy consumption is not available on a county-by-county basis. Therefore, the estimates used in this study are based on total energy consumption for each state (reported in the latest DOE State Energy Data Report [1980 data]),[6] divided into counties in proportion to population. The 1980 Bureau of Census population totals for state and county were used to compute the percent of the state's population in each county of the study area.[7] These data are presented in Appendix C, along with the land area that was used in these and other calculations for area source estimates. The resulting estimates of residential and commercial energy consumption for all 150 counties in the study area are presented in Section 4.

The estimate of fuel consumption for the transportation sector is based on the number of registered vehicles in each

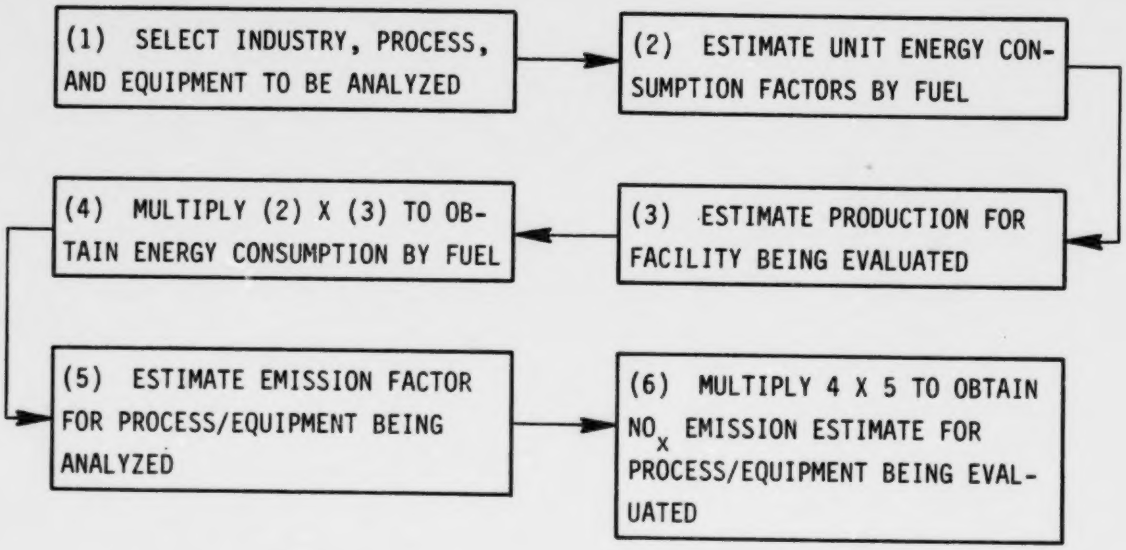
(1) SELECT INDUSTRY, PROCESS, AND EQUIPMENT TO BE ANALYZED
(2) ESTIMATE UNIT ENERGY CONSUMPTION FACTORS BY FUEL
(3) ESTIMATE PRODUCTION FOR FACILITY BEING EVALUATED
(4) MULTIPLY (2) X (3) TO OBTAIN ENERGY CONSUMPTION BY FUEL
(5) ESTIMATE EMISSION FACTOR FOR PROCESS/EQUIPMENT BEING ANALYZED
(6) MULTIPLY 4 X 5 TO OBTAIN NOx EMISSION ESTIMATE FOR PROCESS/EQUIPMENT BEING EVALUATED

Figure 3-2. Methodology for estimating point-source fuel consumption and NO_x emissions.

county applied as a share of the total state motor vehicle consumption of gasoline and diesel fuel. Data on the number of vehicle registrations was purchased from R. L. Polk and Company, which publishes these data annually. This approach was used to ensure uniformity for all of the estimates.

3.3.4 Residual Industrial Area Sources

The major point source analysis described earlier resulted in an estimate of total fuel consumption for all direct-fired processes greater than 100×10^6 Btu/yr in the study area. The fuel use in boilers with capacities greater than 250×10^6 Btu/h had already been quantified. The fuel consumption for these direct-fired processes and boilers was then deducted from the total for the industrial sector (obtained from the State Energy Data Report), and the balance was treated as a residual area source fuel consumption. This residual includes fuel consumption from boilers smaller than 250×10^6 Btu/h, small combustors less than 100×10^9 Btu/yr, gas turbines, and IC engines. Development of a completely satisfactory means of allocating total residual industrial fuel consumption by county was beyond the current scope of work. Nevertheless, a residual fuel consumption estimate for the 150-county study area was made by using population as an allocation method to demonstrate the magnitude of residual source fuel and NO_x emissions. The results of this analysis are presented in Section 4.

3.3.5 Identification of NO_x Emission Factors

The assignment of NO_x emission factors to individual combustion processes was based on a review of EPA's published factors[8] and other data from the literature. It was found that NO_x emission factors are not available for a substantial number of combustion processes. Whenever an NO_x emission factor could not be located, a general emission factor graph (for oil-and gas-fired sources) that estimates NO_x emissions as a function of heat input from the fuel was used. It should be noted that no attempt was made to find the most accurate emission factor for all point sources on Table 3-3. Once the population of processes actually found in the study area had been identified, further study of emission factors was limited to this group.

The NO_x emission factors for boilers and area sources were better documented, and these sources presented no problems. Tables 3-3 and 3-4 present the resulting list of emission factors for each combustion process. Figures 3-3 and 3-4 present the general NO_x emission factor graphs for oil and gas.

3.3.6 Development of NO_x Emission Estimates

The development of NO_x emission estimates was straightforward. Fuel consumption estimates for point and area sources were multiplied by the corresponding NO_x emission factor to obtain NO_x emissions. The NO_x emissions for point sources were calculated for each facility and process, and the results were totaled (by equipment and fuel type) for the 150-county study area. All area source NO_x emissions were carried to the county level, and overall NO_x emissions from each major sector were also summarized by state. Results of the NO_x emission estimates are presented in Section 4.

TABLE 3-4. NO_x EMISSION FACTORS FOR INDUSTRIAL BOILERS AND AREA SOURCES

Emission source	Category	Suggested emission factors[8,14]
Industrial boilers[9]	-	Coal: 14 lb/ton[a]
	-	RO: 55 lb/10^3 gal[a]
	-	NG: 140 lb/10^6 cu ft[a]
Area source[15]	Transportation	Gasohol: 90 lb/10^3 gal
	-	Diesel: 300 lb/10^3 gal
	Commercial	Coal: 6 lb/ton
	-	RO: 60 lb/10^3 gal
	-	DO: 20 lb/10^3 gal
	-	NG: 120 lb/10^6 cu ft
	Residential	Coal: 4.5 lb/ton
	-	CO: 18 lb/10^3 gal
	-	NG: 100 lb/10^6 cu ft

[a] Emission factors applied to MFBI data; for NEDS boilers total reported NO_x emissions were utilized.

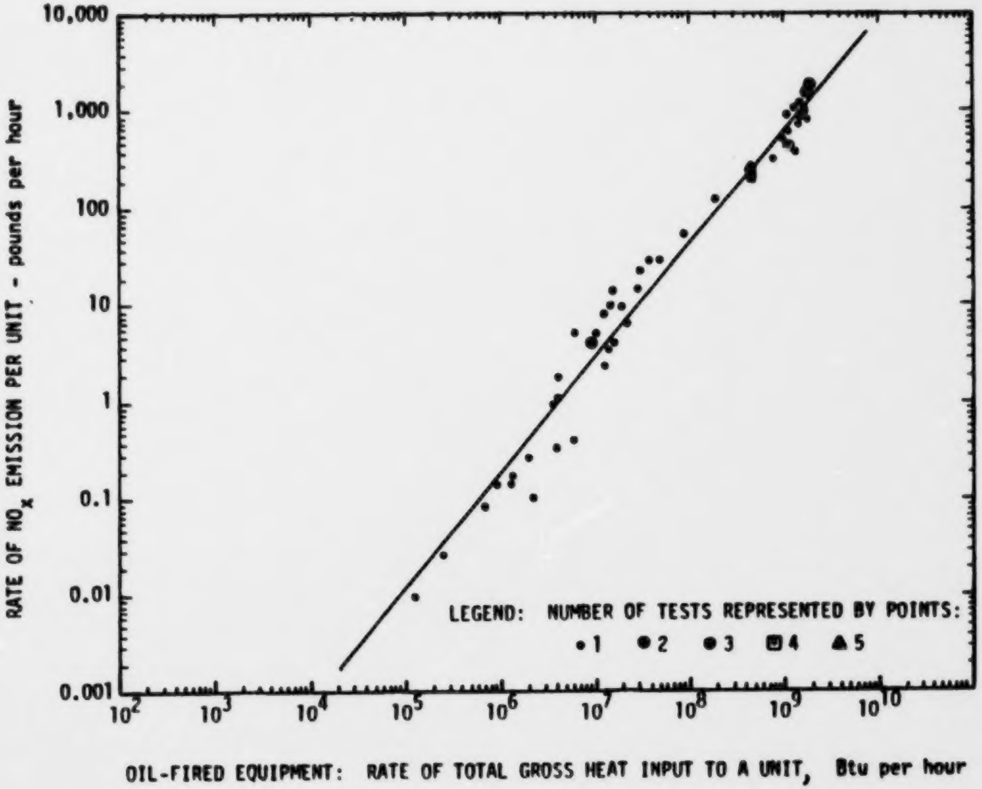

Figure 3-3. Graph for estimating NO_x emissions from oil-fired equipment.[9]

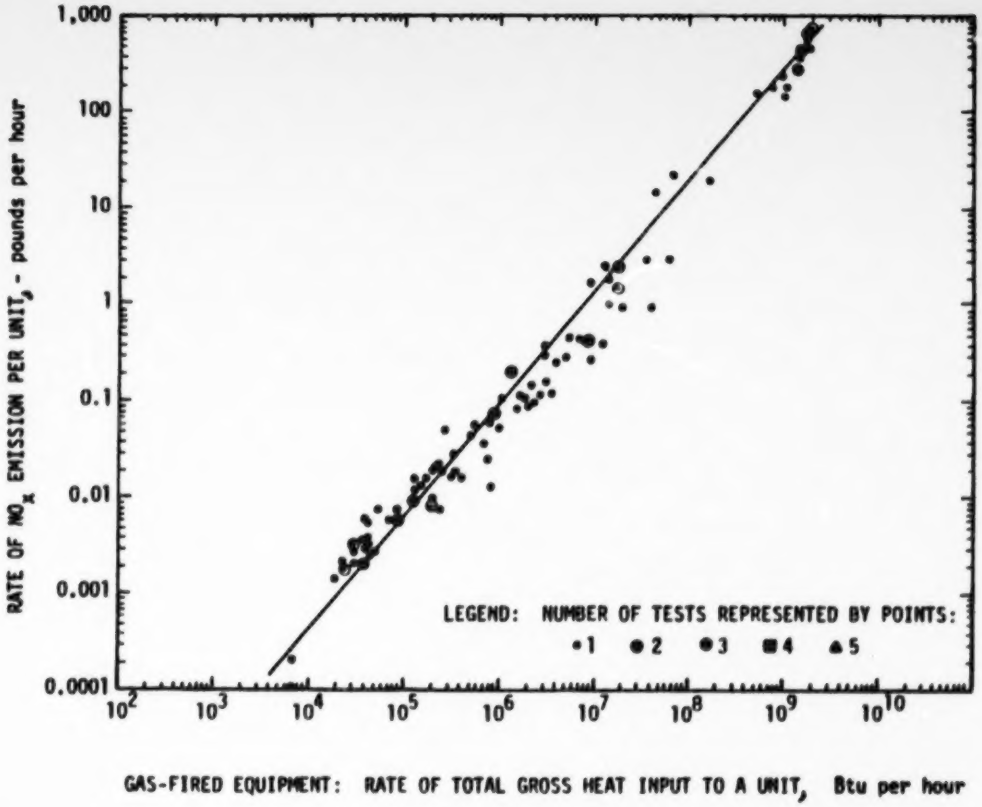

Figure 3-4. Graph for estimating NO_x emissions from gas-fired equipment.[9]

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SECTION 4

DISCUSSION OF RESULTS

This section summarizes the results of the analysis to accomplish the following: 1) identify point sources in the 150-county study area, 2) develop fuel consumption estimates for each combustion process identified, and 3) develop the NO_x inventory for all point and area combustion sources.

Limited funds made it necessary to restrict the scope of this study. Because numerous earlier surveys and inputs to the National Emissions Data System have placed strong emphasis on the electric utility sector, it appeared that relatively complete and reliable information on fuel usage and an NO_x inventory for that sector were readily available. Thus, as indicated earlier, it was decided to obtain NO_x emission estimates directly from data supplied by the National Emissions Data System and to include these data in the study area results for comparison purposes. Hence, most of the following discussions on point sources in this section relate specifically to those associated with industrial activities (excluding power generation). Section 4.3 (Analysis of NO_x Emissions) does, however, contain a brief description of the approach used to derive the NEDS-based emissions data for the electric utility sector.

4.1 IDENTIFICATION OF INDUSTRIAL SECTOR POINT SOURCES

The analysis identified 73 industrial processes classified as major point sources. In each of these classifications, one or more processes were associated with the 28 types of facilities listed in Table 3-3 along with derived emission factors for individual processes.

Future studies may result in modifications to the list of 73 major point sources. Nevertheless, the list represents the product of what is believed to be the first attempt to identify all direct-fired processes that consume significant amounts of fossil fuel. Review of the list by experts and comparisons with listings of combustion processes in NEDS have revealed no obvious omissions; hence, the list is believed to be sufficiently complete for present purposes. Twenty types of facilities within the study area have 43 of the 73 major point sources that have been identified as making the national population.

Table 4-1 summarizes the number of point sources by industry and facility type that were identified in the 150-county study area. The table also presents the number of direct-fired facilities on a national basis. As indicated, 222 direct-fired facilities were located in the study area, compared with approximately 3200 direct-fired plants for the same industries nationwide.

Table 4-2 summarizes the number of facilities in the study area found to have industrial boilers with capacities equalling or exceeding 250 x 10^6 Btu/h. Forty individual facilities containing boiler installations that meet these criteria were found

TABLE 4-1. ESTIMATES OF THE NUMBER OF PLANTS IN THE 150-COUNTY STUDY AREA AND IN THE UNITED STATES

Industry/facility	Number of plants in study area	Approximate number of plants in the U.S.
Petroleum refining		
Petroleum refinery	6	324
Petrochemicals		
Ammonia plants	2	77
Phosphate rock and basic fertilizer		
Sodium phosphate plants	2	15
Pulp and paper		
Kraft pulp mills	5	120
Mineral products		
Gypsum plants	9	72
Lime plants	10	151
Clay products		
Brick and tile plants	13	214
Lightweight aggregate plants	1	35
Cement	14	161
Glass		
Container glass plants	15	109
Flat glass plants	1	28
Pressed and blown glass plants	9	83
Mineral wool	4	26
Iron and steel		
Integrated plants	5	57
Mini and midi plants	11	100
Iron foundries	64	1396
Secondary nonferrous metals		
Copper smelters and refineries	19	43
Lead smelters	9	89
Aluminum smelters	13	58
Aluminum fabrication		
Aluminum sheet, plate and foil plants	10	68
Total	222	3326

TABLE 4-2. DISTRIBUTION OF INDUSTRIAL BOILERS WITH CAPACITIES OF >250 x 10^6 Btu/h IN THE 150-COUNTY STUDY AREA

State	No. of counties in study area	No. of counties with facilities having boilers >250 x 10^6 Btu/h	No. of facilities having boilers >250 x 10^6 Btu/h
Connecticut	8	3	6
Massachusetts	11	1	3
New Hampshire	10	2	2
New Jersey	15	4	8
New York	59	13	15
Pennsylvania	18	4	4
Rhode Island	5	2	2
Vermont	14	0	0
	150	29	40

in 29 of the 150 counties in the study area. Previous studies have estimated that there are approximately 1200 individual industrial boiler units larger than 250 x 10^6 Btu/h in the United States.[1]

Appendix D summarizes fuel consumption and NO_x emission data for each of the direct-fired and boiler facilities located in the study area and for traditional area sources (i.e., the residential, commercial, and transportation sectors). The following subsections summarize pertinent fuel and NO_x emission data for both point and area sources.

4.2 FUEL CONSUMPTION ESTIMATES

Table 4-3 summarizes fuel consumption in the transportation, residential, commercial, and industrial sectors by state for the 150-county study area. Among the traditional area sources, the transportation sector consumes the most energy. The use of diesel fuel and gasoline in transportation accounts for 35 percent of total fuel consumption in the study area. In the residential and commercial sectors combined, natural gas and distillate each contribute about 45 percent of the total. In the commercial sector only, residual oil usage roughly equals that of natural gas and distillate oil. All area sources combined (including residual area sources) account for 92 percent of total fuel consumption in the study area (except that consumed by utilities, which was not included as part of this study). More details relative to types of fuels used in various sectors are presented in Appendix C.

TABLE 4-3. FOSSIL FUEL CONSUMPTION IN THE 150-COUNTY STUDY AREA
(trillion Btu)

State	Traditional area sources			Industrial point sources				Fuel totals		
	(1) Transportation	(2) Residential	(3) Commercial	State total[a]	(4) Direct-fired	(5) Boiler	(6) Residual	Point 4 & 5	Area 1, 2, 3, & 6	State total
Connecticut	170.3	134.4	54.0	91.8	8.1	6.6	77.1	14.7	435.8	450.5
Massachusetts	289.6	226.5	120.5	91.0[b]	6.0	4.3	80.7	10.3	717.3	727.6
New Hampshire	51.2	28.5	6.1	9.6	6.8	2.0	0.8	8.8	86.6	95.4
New Jersey	369.2	211.3	136.4	260.7[c]	75.5	14.2	171.0	89.7	887.9	977.6
New York	675.6	558.6	364.5	517.7[d]	83.8	92.9	341.0	176.7	1939.7	2116.4
Pennsylvania	251.8	157.3	54.4	419.8[e]	87.4	28.5	303.9	115.9	767.4	883.3
Rhode Island	49.0	42.1	15.1	15.0	1.9	0.5	12.6	2.4	118.8	121.2
Vermont	33.7	19.6	4.2	7.8	0	0	7.8	0	65.3	65.3
Study area total	1890.4	1378.3	755.2	1413.4	269.5	149.0	994.3	418.5	5018.8	5437.3

[a] Based on 1979 data.[2]

[b] Value is 97 percent of 1979 state total (93.8×10^{12} Btu). Reflects counties comprising study area. Based on population.

[c] Value is 84 percent of 1979 state total (310.4×10^{12} Btu). Reflects coutnies comprising study area. Based on population.

[d] Value is 97 percent of 1979 state total (533.7×10^{12} Btu). Reflects counties comprising study area. Based on population.

[e] Value is 33 percent of the 1979 state total (1272.2×10^{12} Btu). Reflects counties comprising study area. Based on population.

In the industrial sector, the residual usage is in 1) boilers with capacities less than 250 x 10^6 Btu/h, 2) small direct-fired fossil-fuel combustors consuming less than 100 x 10^9 Btu/yr, and 3) miscellaneous combustors (gas turbines, driers, ovens, etc.). Obtaining values for residual fuel use and NO_x emissions on a county-specific basis required a breakdown of total statewide industrial fuel use to a county level. Although population data, land area, and the number of industrial establishments could all be used to model this breakdown, none of these approaches yielded results that were totally satisfactory for allocating total industrial fuel consumption by county. As a demonstration of the methodology, the ratio of population in the study area to total state population was used to allocate total industrial fuel consumption. This provided a total for the study area that served as a basis for calculating residual fuel consumption and NO_x emissions.

In general, the direct-fired sources and boilers identified account for a relatively small percentage of total industrial fuel consumption (30 percent for the 150-county study area). The residual energy usage is therefore sizable. Of the industrial fuel consumption, 419 x 10^{12} Btu is used in specifically identified major point sources (boilers and direct-fired processes). Over twice this amount (994 x 10^{12} Btu) comprises residual industrial consumption (fuel that is burned in small boilers, driers, IC engines, gas turbines, and a multitude of small combustors). National studies have shown that energy consumption for direct-fired processes is somewhat higher than for boilers (about 7 x

10^{15} Btu vs. 6.0 x 10^{15} Btu) but not on the order of 2 to 1 as indicated by the study area results. This probably reflects the higher limit of 250 x 10^6 Btu/h used to classify boilers as major point sources for the study. The results also suggest that a substantial residual fuel consumption of about 800 x 1012 Btu would still be associated with unidentified combustion sources, even if boilers and direct-fired processes had been identified to the extent that consumption was about equal. Another possibility is that a large portion of the residual fuel consumption represents boilers with capacities less than 250 x 10^6 Btu/h. The actual composition of the residual population, however, is unknown.

A breakdown of energy consumption by fuel for the various direct-fired facility types is shown in Table 4-4. Natural gas accounts for about 37 percent of the total direct-fired fuel consumption in the study area. "Other fuels" (primarily waste fuels) is the next largest category at 33 percent, followed by coal at 17 percent, oil at 7 percent, and coke at 6 percent. Integrated iron and steel plants and petroleum refineries were the highest consumers of direct-fired energy.

Boiler fuel consumption breakdowns by plant are presented in Appendix D. The largest fuel source is residual oil, which represents 58 percent of the total; this is followed by coal (23 percent), blast furnace gas (9 percent), natural gas (7 percent), coke oven gas (2 percent), and distillate oil (1 percent).

In summary, the limited amount of fuel consumption data available for direct-fired processes makes it impossible to determine the degree to which the results of this study reflect

TABLE 4-4. ESTIMATED FUEL CONSUMPTION AND NO_x EMISSIONS POINT SOURCES IN THE 150-COUNTY STUDY AREA

	Energy consumption, 10^9 Btu/yr						
Industry/Facility	Coal	Coke	Oil	Natural gas	Other	Total fuel	Total NO_x TPY
Petroleum refining	0	0	3,376	16,881	47,268	67,525	5,147
Petrochemicals (ammonia)	0	0	0	1,916	0	1,916	345
Sodium phosphate	0	0	68	690	0	758	20
Pulp and paper	445	0	6,856	0	0	7,301	1,275
Gypsum	0	0	0	979	0	979	77
Lime	12,875	0	759	4,791	467	18,892	3,311
Clay products (brick and tile)	0	0	0	5,570	0	5,570	197
Clay products (aggregate)	390	0	0	0	0	390	225
Cement	31,656	0	304	1,860	0	33,820	7,452
Glass (container)	0	0	0	13,489	0	13,489	5,652
Glass (flat)	0	0	0	2,130	0	2,130	490
Glass (pressed and blown)	0	0	0	5,940	0	5,940	757
Mineral wool	0	408	0	0	0	408	168
Iron and steel (integrated)	0	0	4,268	25,174	42,839	72,281	23,888
Iron and steel (mini and midi)	0	0	361	2,275	0	2,636	728
Iron and steel (iron foundries)	0	13,858	0	0	0	13,858	254
Secondary nonferrous (aluminum)	0	0	1,567	4,700	0	6,266	26
Secondary nonferrous (copper)	48	2,130	48	168	0	2,394	983
Secondary nonferrous (lead)	0	75	52	161	0	288	60
Aluminum (sheet, plate, and foil)	0	0	570	12,100	0	12,670	1,530
Total	45,414	16,470	18,229	98,824	90,574	269,511	52,585

national fuel consumption patterns. It is reasonable to assume that these results may reflect the fuels preferred for individual processes, but with no data for 30 of major point sources that have been identified (because they are not present in the study area) and limited data for others that are present in the study area, extrapolation from study area results is impossible.

Boiler fuel consumption patterns in the study area appear to be atypical of national patterns in that residual oil, known to be burned in larger quantities in the Northeast than in most of the rest of the United States, is the main fuel.

4.3 ANALYSIS OF NO_x EMISSIONS

The electric utility sector utilizes coal, residual, and distillate fuel oils, and natural gas to provide more than 99 percent of the fossil-fuel heat input. The NO_x emissions generated by these fuels are due primarily to the method of fuel combustion and to the nitrogen content of the fuels. Emission factors from EPA's Compilation of Air Pollutant Emission Factors and NEDS Source Classification Codes and Emission Factor Listing, AP-42, were used in conjunction with fuel consumption data to estimate the uncontrolled NO_x emissions from electric utilities in 1978.

All coal was assumed to have been fired in dry-bottom, pulverized-coal-fired units with an emission factor of 18 pounds NO_x per ton of coal fired. For boilers firing residual oil, AP-42 lists two NO_x emission factors, one for tangential firing and another for normal firing. An average of these two values, 78 pounds of NO_x emitted per 1000 gallons of residual oil fired, was used in these estimates. The value of 105 pounds of NO_x per 1000 gallons of No. 2 distillate oil is the NEDS emission factor. As with residual oil, AP-42 gives two NO_x emission factors for natural gas, one for tangential boilers and one for nontangential boilers. An average value, 500 pounds of NO_x per million cubic feet of natural gas fired, was used in these estimates.

By use of the above methods, estimates were made of the 1978 NO_x emissions generated by fossil-fuel consumption in the electric utility sector. The values obtained for the 150-county area included in this study are shown in Table 4-5.

Figure 4-1 summarizes the contribution of various sectors to only stationary source NO_x emissions. Electric utilities account for 58.3 percent of stationary source NO_x emissions, followed by the industrial sector at 22.8 percent and residential/commercial at 18.9 percent.

Table 4-5 presents a summary of all categories of NO_x emissions for the study area. Comparison of these NO_x emissions data with comparable data for fuel consumption presented in Table 4-3 show that the relationships between the various sectors change considerably. For example, motor vehicles consume around 30 percent of the fuel, but they produce about 48 percent of the NO_x in the study area. This is typical of the Nation on the whole, for which NO_x from transportation amounts to 50 to 55 percent.

The industrial residual NO_x emissions in the 150 counties amounted to an estimated 98 x 10^3 tons (approximately 5.9 percent of the total). It should be noted that this value was obtained

TABLE 4-5. SUMMARY OF POINT AND AREA SOURCE NO_x EMISSIONS IN THE 150-COUNTY STUDY AREA (10^3 short tons)

State	Area sources				Point sources			NO_x total			
	Traditional				Industrial						
	(1) Transportation	(2) Residential	(3) Commercial	(4) Industrial residual	(5) Boilers	(6) Direct fired	(7) Electric utility	Industrial 4, 5, and 6	Area 1, 2, 3, and 4	Point 5, 6, and 7[a]	State total
Connecticut	71.7	8.3	3.9	13.0	1.2	1.3	33.4	15.5	96.9	35.9	132.8
Massachusetts	118.7	13.6	10.9	8.8	1.1	0.8	78.3	10.7[b]	152.0	80.2	232.2
New Hampshire	21.3	1.8	0.4	0.7	0.4	1.1	12.2	2.2	24.2	13.7	37.9
New Jersey	161.9	12.2	16.5	9.4	2.6	9.3	55.4	21.3[c]	200.0	67.3	267.3
New York	274.9	31.8	42.7	12.2	34.2	16.3	191.9	62.7[d]	361.6	242.4	604.0
Pennsylvania	117.4	8.8	4.6	51.7	4.3	23.6	124.5	79.6[e]	182.5	152.4	334.9
Rhode Island	20.2	2.6	1.2	1.6	0.1	0.2	2.1	1.9	25.6	2.4	28.0
Vermont	15.1	1.3	0.3	1.1	0	0	0.1	1.1	17.8	0.1	17.9
Study area total	801.2	80.4	80.5	98.5	43.9	52.6	497.9	195.0	1060.6	594.4	1655.0

[a] Based on 1978 data.[3]

[b] Value is 97 percent of 1978 state total based on the population of the counties included in the analysis.

[c] Value is 84 percent of 1978 state total based on the population of the counties included in the analysis.

[d] Value is 97 percent of 1978 state total based on the population of the counties included in the analysis.

[e] Value is 33 percent of 1978 state total based on the population of the counties included in the analysis.

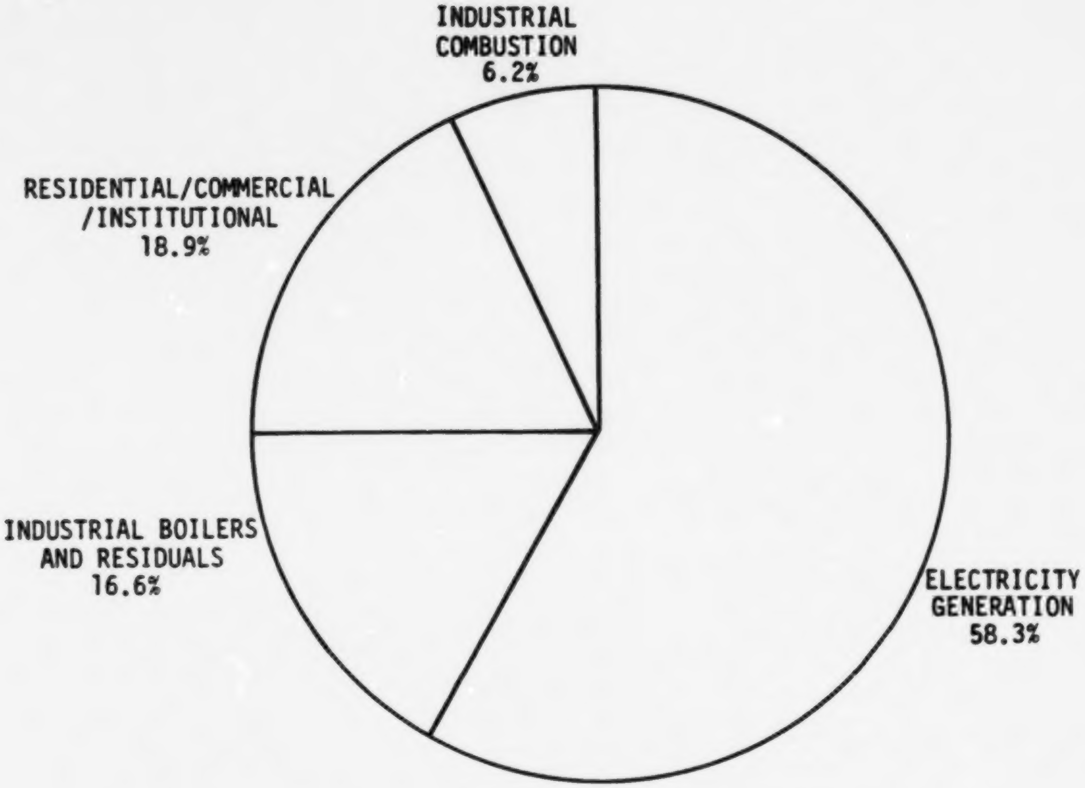

Figure 4-1. Relative contributions of various sectors to stationary source NO_x emissions in the 150-county study area.

by using values for industrial NO_x emissions estimated for individual states in an earlier study[3] and adjusting them (with population ratios) to derive estimates for NO_x emissions inside and outside of the study area in the individual states. The NO_x emissions for direct-fired processes and boilers in the study area were then subtracted from the state estimates to derive the values presented in Table 4-5.

The use of population ratio data was necessary for this study because the study region was made up of portions of states. For a study involving the use of entire states, the general approach described in Section 3 would be used. It should be noted that computation of an emission factor based on NO_x values and fuel consumption gave an average emission factor of around 0.3 $lb/10^6$ Btu. This is not unreasonable when it is considered that many emission factors for small boilers, gas turbines, etc. range from 0.2 to 0.7 lb $NO_x/10^6$ Btu.

No analysis was made of the relative contributions of small combustors and small boilers to the residual industrial source NO_x emissions. A preliminary estimate was made of the potential contribution of natural gas turbines to these emissions, based on the miles of pipeline in the eight-state study area. The results showed the gas turbine contribution to be on the order of 10 percent of the residual NO_x emissions, based on an emission factor of 0.5 $lb/10^6$ Btu. Gas turbine fuel consumption, by comparison, was only 2 percent of total fuel consumption in the study area.

Area source NO_x emissions (which includes industrial sector sources) amount to 1061 x 10^3 tons/yr. This is 64 percent of total NO_x emissions in the study area. The dominance of the transportation sector (48 percent of total NO_x emissions) over all other point and area sources is apparent in all states of the study area except Pennsylvania. In this highly industrialized state, electric power generation accounts for more NO_x emissions than does the transportation sector. The residential and commercial sectors combined account for 9.7 percent of total NO_x emissions. Industrial point and residual (area) source NO_x emissions are almost identical, each accounting for slightly less than 6 percent of the total.

Table 4-6 summarizes direct-fired NO_x emissions in the 150-county study area by equipment and facility type. Boiler NO_x emissions from all industries are also included for comparison. The industrial boiler NO_x emissions account for about 45 percent of the total industrial point source NO_x emissions in the study area; thus industrial boilers represent by far the major NO_x-emitting equipment outside of utility boilers.

The range for estimated annual NO_x emissions from the 20 types of facilities in the study area are shown in Table 4-7. These data show that emissions from individual facilities range from 1 ton/yr for the smallest facilities to more than 2,800 tons/yr for the largest refinery and 10,640 tons/yr for the largest integrated iron and steel plant.

Many of the factors contributing to the wide range are identifiable:

TABLE 4-6. EMISSIONS BY TYPE OF COMBUSTION EQUIPMENT AND FACILITY IN THE 150-COUNTY STUDY AREA

Equipment	Industry/Facility	NO_x Emissions TPY	Total NO_x Emissions TPY
Boiler - Coal	All	24,301	
Residual oil	All	14,405	
Natural gas	All	2,913	
Blast furnace gas	Iron and steel (integrated)	1,810	
Coke oven gas	Iron and steel (integrated)	280	
Distillate oil	All	235	43,944
Kiln	Cement	7,452	
	Lime	3,311	
	Pulp and paper	1,275	
	Clay products (aggregate)	225	
	Gypsum	77	
	Sodium phosphate	9	12,349
Reheat furnace	Iron and steel (integrated)	5,905	
	Aluminum (sheet, plate, foil)	822	
	Iron and steel (mini and midi)	658	7,385
Melting furnace	Glass (container)	5,652	
	Glass (pressed and blown)	757	
	Glass (flat)	490	6,899
Open hearth	Iron and steel (integrated)	5,463	5,463
Process heater	Petroleum refining	5,147	5,147
Soaking pit	Iron and steel (integrated)	3,050	
	Iron and steel (mini and midi)	70	3.120

(continued)

TABLE 4-6 (continued)

Equipment	Industry/Facility	NO_x Emissions TPY	Total NO_x Emissions TPY
Sinter plant	Iron and steel (integrated)	3,941	3,941
Coke plant	Iron and steel (integrated)	4,080	4,080
Reverberatory furnace	Secondary nonferrous (copper)	890	
	Aluminum (sheet, plate, foil)	708	
	Secondary nonferrous (aluminum)	9	
	Secondary nonferrous (lead)	46	1,653
BF stove	Iron and steel (integrated)	1,444	1,444
Cupola	Iron and steel (iron foundries)	254	
	Mineral wool	168	422
Tubular furnace	Petrochemicals (ammonia)	345	345
Sweating furnace	Secondary nonferrous (aluminum)	17	
	Secondary nonferrous (copper)	14	31
Brick kiln	Clay products (brick and tile)	197	197
Blast Furnace	Secondary nonferrous (copper)	79	
	Secondary nonferrous (lead)	14	93
Dryer	Sodium phosphate	11	11
Electric furnace	Iron and steel (integrated)	5	5
Total - All equipment			96,529

TABLE 4-7. NO_x EMISSIONS RANGE BY MAJOR INDUSTRIAL POINT SOURCE

Facility/process	NO_x emissions range, tons/yr
Petroleum refineries	37 - 2805
Petrochemical plants/ammonia	107 - 238
Phosphate rock and basic fertilizer plants/sodium phosphate	3 - 17
Pulp mills	31 - 1044
Gypsum plants	6 - 21
Lime plants	29 - 1033
Brick and tile plants	6 - 27
Lightweight aggregate plants	225[a]
Cement plants	64 - 1308
Container glass plants	52 - 712
Flat glass	490[a]
Pressed and blown glass plants	14 - 200
Mineral wool plants	42[b]
Integrated steel plants	858 - 10,640
Iron foundries	2 - 16
Mini and midi steel plants	15 - 185
Secondary aluminum smelters	2[b]
Secondary copper smelters and refineries	41 - 245
Secondary lead smelters	1 - 21
Primary aluminum fabrication plants	153[b]

[a] Only one plant in study area.

[b] Data needed for individual plant NO_x estimates not available. Average value used for all plants in the category.

1) Because plants were selected on the basis of estimated fuel consumption, those with low emission rates are minor NO_x contributors despite relatively high fuel consumption; e.g., foundries plant fuel consumptions of almost 900 x 10^9 Btu/yr produce only 16 tons/yr of NO_x.

2) The number and size of processes vary widely among facilities; e.g., one refinery employing only atmospheric distillation produces 37 tons/yr, whereas one large refinery with a full range of processes produces 2800 tons/yr.

3) The production rate and associated NO_x emissions at many plants vary widely because of market factors; e.g., in 1977 integrated iron and steel facilities were operating at 67.4 percent capacity, whereas as recently as September 1982 production capacity was 39.8 percent.

Even though the NO_x emission data vary between and within individual categories, they provide an interesting perspective on the emissions that would be expected over the entire population of combustion processes in the United States.

The emissions generated by individual industrial boiler facilities vary widely, depending on fuel type, the quantity burned, and boiler type. Some installations with low capacity factors may emit only a few tons of NO_x per year, whereas others release many thousands of tons. As an illustration of this wide variation, a single industrial installation in New York accounts for more NO_x than the other 39 boiler facilities in the study area. If this facility is excluded from the total, the average for the others is about 500 tons of NO_x per year. The relative proportion of industrial NO_x emissions by SIC category is as follows:

- SIC 38 - Instruments and Related Products, 51 percent
- SIC 33 - Primary Metals Industries, 18 percent
- SIC 26 - Paper/Allied Products, 9 percent
- SIC 28 - Chemicals and Allied Products, 7 percent
- All others - 15 percent

A more detailed breakdown of NO_x emissions for boilers is presented in Appendix D.

Coal-fired industrial boilers emit the most NO_x (24,301 tons or 55 percent of the total). Boilers firing residual oil are next at 33 percent, followed by those firing natural gas (7 percent), blast furnace gas (4 percent), coke oven gas (0.6 percent), and distillate oil (0.4 percent).

The estimated industrial boiler NO_x emissions indicate that the limited boiler sample in the study area is atypical of the total population. The distribution by SIC category shown above, is dominated primarily by large boilers in SIC 38 - Instruments and Related Products (photographic equipment and supplies, etc.), a category that is relatively unimportant on a national total.

For direct-fired industrial point sources, the largest equipment category is the rotary kiln (present in a number of facility types), followed by reheat furnaces and glass-melting furnaces. The iron and steel industry as a whole accounted for the largest percentage of NO_x emissions from direct-fired sources in the study area (24,870 tons or 47 percent of the total of 52,585 tons for all major direct-fired sources).

On a national basis, the significance of the distribution shown for NO_x emission from direct-fired processes in the study area is doubtful, as was the distribution of fuel burned in such processes.

An attempt was made to compare point and area source NO_x emissions in the study area with national totals. Table 4-8 summarizes the results of this analysis. These comparisons show

TABLE 4-8. COMPARISON OF NO_x EMISSIONS IN THE 150-COUNTY STUDY AREA WITH 1977 NATIONAL TOTALS FOR COMPARABLE CATEGORIES

	National NO_x emissions,[a,b] 10^3 ton/yr	150-county study area	
		10^3 ton/yr	Percent of national total
Mobile source fuel combustion			
Highway vehicles	7255.8 (37.6%)	801.2	11.2
Stationary source fuel combustion			
Electric generation	7597.3 (39.4%)	497.9	6.6
Industrial (boilers and residual sources)	2611.9 (13.5%)	142.4	5.4
Residential/commercial/institutional	811.3 (4.2%)	160.9	19.8
Industrial process and combustion[c]			
Chemicals	186.7 (1.0%)	0.3	0.2
Petroleum refining	442.2 (2.3%)	5.1	1.2
Metals	81.6 (0.4%)	26.4	32.4
Mineral products	232.6 (1.2%)	19.4	8.3
Wood products	47.6 (0.2%)	1.3	2.7
Other industrial processes	21.3 (0.1%)	0.0	0.0
Totals	19,288.3 (100%)	1655.0	8.6

[a] Based on data from Reference 4.

[b] Numbers in parentheses represent percentage of total emissions.

[c] Current study figures represent only industrial, combustion NO_x emissions.

that overall NO_x emissions in the 150-county study area account for about 8.6 percent of the nationwide estimates for comparable categories. It should be noted that the industrial process estimates from NEDS includes both combustion and process NO_x emissions. This means that the study area emissions as a percentage of national emissions would be somewhat higher if only combustion-related emissions were compared.

The only comparison in the table that appears to be unusual is the metals industry. The iron and steel industry comprises 82 percent of the 27,900 tons identified by NEDS for the entire metals industry in the study area. Because only 5 (9 percent) of the 57 integrated plants in the United States are located in the study area, it is unusual that iron and steel industry NO_x emissions could account for 36 percent of the national total of all NO_x emissions from the metals industry.

One possibility is that AP-42, which is used as the basis for NEDS calculated emissions, does not contain NO_x emission factors for a number of iron and steel processes. This would cause the 81.6×10^3 tons of NO_x per year shown for metals (64.1×10^3 tons of which are from primary metals plants) to be significantly low. A number of additional references were utilized to estimate emission factors, and it is believed that the data on unit energy consumption so derived are likewise well documented. Nevertheless, this anomaly indicates that further study should be given to the iron and steel industry.

A limited comparison of our data with that contained in the 1980 NEDS listings produced the results shown in Table 4-9. The

TABLE 4-9. COMPARISON OF NO_x EMISSIONS ESTIMATES FOR THE 150-COUNTY STUDY AREA WITH 1980 NEDS VALUES

Emission source	NO_x estimates, 10^3 tons/yr	
	1980 NEDS values	This study
Mobile source fuel combustion		
Highway vehicles	894.1	801.2
Stationary source fuel combustion		
Electric generation	423.7	497.9
Industrial (boilers and residual sources)	194.2	142.4
Residential/commercial/institutional	168.6	160.9
Industrial proces and combustion	24.8	52.6
Chemicals	(3.36)	(0.3)
Petroleum refining	(3.07)	(5.1)
Metals	(2.69)	(26.4)
Mineral products	(11.65)	(19.4)
Wood products	(0.25)	(1.3)
Other categories	(3.81)	(0.0)
Mobile source subtotal	894.1 (52.4%)	801.2 (48.4%)
Stationary source subtotal	811.3 (47.6%)	853.8 (51.6%)
Total	1705.4	1655.0

comparison showed fair agreement in most areas. The methodology used in this report to estimate 1977-1980 values accounted for 97 percent of the NO_x emissions estimated for 1980 by NEDS. It appears that NEDS inputs, particularly in the industrial process combustion area, may not account for the total NO_x emissions for that sector.

In the case of foundries, NEDS proved to be useful for determining capacity factors by size range, although some of the data were invalid because of keypunch errors or incorrect input. A comparison of the list of sources from the Penton Directory[5] with the NEDS listing, however, indicated that some foundries were on one list but not the other.

For industrial boilers, both NEDS and MFBI were examined, but the more recent NEDS data were used whenever a conflict arose.

With respect to data sources, it was concluded that the NEDS data base alone does not provide an adequate means of estimating energy consumption and emissions because of problems concerning how the data were derived and whether the input is correct. The methodology developed and demonstrated in this report is believed to be a valuable supplement for checking the validity of NEDS data, as well as an alternative means of estimating energy consumption and pollutant emissions from combustion processes.

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SECTION 5

CONCLUSIONS

5.1 CONCLUSIONS

The results led to conclusions with respect to:

1) The degree to which the inventory methodology demonstration was successful.

2) The significance of the results of the emissions inventory for the 150-county study area.

5.1.1 Conclusions Regarding Inventory Methodologies

Conclusions regarding the success of the inventory methodology are as follows:

1) The methodology for developing a major industrial point source combustion population (i.e., use of Standard Industrial Classification Codes) was judged to be successful. The resulting list of 28 facilities and 73 processes is comprehensive enough to include all combustion sources of any consequence as far as fuel consumption and NO_x emissions are concerned. The data base can also be used to calculate emissions of other combustion-related pollutants.

2) The methodologies developed for calculating industrial plant production, direct-fired fuel consumption, and NO_x emissions do not rely on survey data from state agencies. Although they have not been optimized in this study, these procedures are straightforward and well documented, and they can be easily modified as new data are uncovered.

3) The procedure for calculating industrial boiler fuel consumption and NO_x emissions, in contrast to the methodology for direct-fired processes, relies heavily on NEDS and other past studies because the principal alternate source of data, MFBI, is believed to be less reliable. The data base for industrial boilers in general, however, is inadequate and does not provide a

sound basis for making estimates of boiler fuel consumption and NO_x emissions. This situation will prevail until a well-conceived survey of the existing industrial boiler population is conducted.

4) Only a preliminary methodology for calculating fuel consumption and NO_x emissions for residual industrial sources could be developed, and improvements are needed. The use of population, land area, nor number of manufacturing establishments provides a totally representative mechanism for allocation of state data to individual counties. For a study that includes individual states in their entirety, it would appear that data from the State Energy Data Base and the Census of Manufacturers could be combined to provide better perspective on the residual component of industrial fuel consumption.

5.1.2 Significance of the Inventory Findings

The following are the significant findings resulting from the study:

1) The results of the inventory show that area sources are the major contributors of NO_x emissions in the study area, accounting for 92 percent of both fuel consumption and NO_x emissions (excluding utilities). If utility NO_x emissions are included in the total, the area source contribution drops to 64 percent. Utility fuel use was not included in this analysis for comparison. Transportation was a dominant area source, accounting for 48 percent of total NO_x emissions in the study area and only 35 percent of total fuel use. This suggests that area source emissions, particularly those from the New York City and neighboring regions where they are highest, may be producing environmental impacts that require further investigation. Also, the high NO_x emissions from residual industrial fuel consumption (compared with emissions from identifiable industrial point sources) suggest the need for further study of this area.

3) Among the major industrial point sources, boilers were the dominant emitter of NO_x emissions, accounting for 45 percent of the industrial sector NO_x emissions. Rotary kilns from various industries combined were a distant second, followed by reheat furnaces in the metals industry and then glass-melting furnaces. The iron and steel industry accounted for the greatest amount of NO_x emissions. Although these results are specific to the 150-county study area and are not necessarily applicable to the remainder of the United States, they do identify possible focal points for

further investigations to define R&D needed for control of NO_x emissions in particular and combustion emissions in general. For example, they emphasize the need for a better boiler inventory, and suggest a need to investigate the other types of equipment found to be important. Glass-melting furnaces (which have received little past attention), that emit very fine particulates along with the NO_x, might prove to be interesting as to the impact they have both in the Northeast and in other parts of the United States.

4) Natural gas and "other fuels" (blast furnace gas, coke oven gas, etc.) accounted for about 62 percent of the total direct-fired industrial energy consumption, whereas residual oil was the most-used boiler fuel, accounting for 52 percent of the total. In the residential and commercial sectors combined, natural gas and distillate were equally major fuels, accounting for about 45 percent each of the total. In the commercial sector, natural gas, distillate, and residual oil were roughly equal. Gasoline was the predominant fuel in the transportation sector, accounting for 91 percent of the total. The breakdown of fuels for the residual sources was not calculated.

The relative contribution of the various fuel types to NO_x pollution appears to be of little practical value at this time. Detailed data on fuel-use patterns in the study area are incomplete, and no single region (such as the Northeast) can be considered typical of the entire United States. More complete information on boiler fuel consumption and the makeup of the residual component (especially IC engines and gas turbines) might, however, make a fuel-use analysis more meaningful.

5.2 FOLLOW-ON EFFORTS THAT WOULD BE BENEFICIAL

Although the methodology investigated here proved successful for the limited area of study, funding limitations restricted the effort to a 150-county area of the United States. Also, the methodology was essentially limited to detailed consideration of the industrial sector. The following additional efforts involving an extension of this methodology would be beneficial in helping to analyze the most important NO_x problem areas as well as the associated acid precipitation problems:

1) Extend the combustion inventory assessment to include the entire United States. This would give a better determination of NO_x emissions from the various contributing nonutility sectors, as well as equipment types that are the most prevalent NO_x emitters. Trends on a state or regional basis could then be compared with national totals.

2) Perform additional analysis of gas turbines and IC engines to determine their distribution and impact on the NO_x emission inventory.

3) Perform additional analysis of the residual industrial sources to reach a better definition of the types of equipment and fuels that contribute to NO_x emissions.

4) Perform additional analysis of the residential and commercial sectors to determine if a breakdown of equipment types would provide a useful tool for further research efforts on controlling NO_x emissions.

5) Improve the industrial boiler data base so that estimates of fuel consumption and NO_x emission estimates are based on more reliable data. Unfortunately, the latest DOE effort to update the MFBI was cancelled. Thus, the methodology would revolve around 1) verifying the present NEDS listings, 2) adding additional listings from the MFBI after checking to determine their validity, and 3) adding other sources of data from the literature and in-house files. The best source of new data, however, would be that already collected under the recent DOE-MFBI survey.

6) Develop recommendations for an industrial boiler survey that would provide an accurate description of the present boiler population and a system for updating it annually with sales data.

7) Perform additional analysis of the so-called "other fuels," which basically consist of byproduct fuels such as refinery gas, black liquor solids, coke oven gas, etc. These fuels account for a significant percentage of the fuel use in direct-fired processes. The emission factors for such fuels could be improved, and more knowledge is needed on where they are used and their impact on NO_x emissions. Also, these fuels account for about 13 percent of the total large boiler fuel use in the study area (more than natural gas and distillate oil combined).

APPENDIX A

A COMPREHENSIVE INVENTORY OF AIR POLLUTION SOURCES

Prepared by

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Pursuant to U.S. Environmental Protection Agency
Contract No. 68-02-3197

April 25, 1982

(Revised August 1, 1983)

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PREFACE

This paper is included as an appendix only to document the conceptual approach to inventory development as it was visualized prior to the project in which it was demonstrated. After-the-fact review indicates that the project went as foreseen except for deliberate changes; e.g., utilities were eliminated from the study, and it was limited to 150 Northeastern counties rather than applied to the entire United States. The report has not been modified to reflect any changes of this nature.

A COMPREHENSIVE INVENTORY OF AIR POLLUTION SOURCES

INTRODUCTION

Since air pollution was first addressed by the Federal government on a national scale in the mid-1950's, there has been concern over identification and ranking of sources of pollution, from the standpoint of the seriousness of their contribution to overall pollution levels. In the earliest days attention was focused on problems perceived to be of greatest importance. First, motor vehicle emissions, then sulfur oxides from power plants and later, other major pollution sources came under consideration. By the late 1960's, the most significant air pollution sources (judged in terms of national annual emissions of major pollutants such as NO_x and SO_x) had been identified and put in some perspective. Unfortunately, there was still no data bank that contained information on the size, type and amount of pollution, location, etc., for all major air pollution sources. Work to develop a more comprehensive inventory was begun in the late 1960's and early 1970's and was provided impetus by enactment of the Clean Air Act of 1970. The Act required development of State Implementation Plans, which in turn required considerably more information than was applicable on the population of sources within many states. The need for further information triggered source inventory activities on the part of both the State and

Federal groups. In 1971 the National Emissions Data System (NEDS) was established to provide a comprehensive data bank containing information on pollutant discharges from all types of area and point sources. Data generated primarily by State agencies have been incorporated in what is basically a "bottom-up" inventory. Data are supplied by the States and entered in the NEDS computerized data base for general use. The quality of the data is controlled by the adequacy of resources available to the State to collect information from the operators of the facilities producing pollution. While input data are to some extent screened, the accuracy of the various data base elements has not been well defined. Some who have used NEDS feel that certain parts, such as the data on power plants and iron and steel plants, are well documented. Data for other more fragmented categories, many of which are associated with small sources, such as foundries, industrial boilers, etc. appear to be poorly documented. Hence, it appears that the State agencies have never supplied NEDS the detailed information needed for an inventory of uniform accuracy.

Over the years, the NEDS has served the needs that have arisen and any quality problems that may exist do not appear to have caused serious problems. In the past several years, however, the need for better and more comprehensive regional and local inventories has been considered in several quarters. The data base for industrial and commercial boilers, for example, has been assessed and is felt to be inadequate, considering the nature of the pollution problem they are not believed to present. Several studies, by EPA and others, have put this problem in as much perspective as the available data permits. DOE efforts to conduct a "Major Fuel Burning Installation" survey that could have provided useful perspective for major facilities was a limited success. Plans for a follow-up survey have been curtailed as an economy measure. Hence, there remains a gap in the information needed for full understanding of the problem. Studies of acid rain have also generated pressure for more accurate inventory data. Earlier assessments, that suggested large coal-burning sources were the major contributors to acid rain, are being questioned. The search for data on emissions from small sources to assess the role of local sources on regional pollution has been disappointing. At present, a number of groups have been searching for better answers.

The need for an independently derived, comprehensive, regionalized source inventory for a variety of uses was considered early in the present "NO_x reassessment" project being developed by IERL/RTP. It was decided to investigate the feasibility of a "top down" assessment that would utilize data on energy consumption that have been developed and refined in recent years to develop an inventory of fuel consumption* that would not be primarily dependent on information supplied by fuel users. The investigation that followed demonstrated the practicality of developing State or regional inventories that would be more complete than any done previously in identification and location of major combustion sources. Also, it demonstrated the feasibility of developing fuel consumption and pollution production estimates for individual facilities.

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* The investigation was limited to combustion sources for demonstration purposes. It was, however, conducted in a manner that would allow conversion of fuel burning estimates to pollutant discharges. Also, it is expected the method investigated would be applicable to other types of inventories such as VOC sources.

THE GENERAL APPROACH

The approach as it has been conceived is novel in that it will begin with an analysis of all consumption of major fossil fuels to:

1) identify all fuel usage categories, and
2) identify the kinds of combustion equipment used within each category.

This analysis will provide a frame of reference for the balance of the study and will permit using an energy accounting methodology to quantify the degree to which the inventoried sources in individual consuming sectors are complete and representative of the total population for the sector.

As a first step, the latest data on fuel consumption available by consuming sector (residential, commercial, industrial, electric utility, and transportation) will be broken down into major usage categories. The first subdivisions for analysis and the amounts of fuel represented by each sector-fuel type category are shown in Table A-1. These categories represent almost 95 percent of the total of 67.7 x 10^{15} Btu of fossil fuel burned in

1979. The balance of about 5 percent is used in applications too small to be of concern or in applications that do not directly contribute to pollution of ambient air (e.g., aircraft fuel, seagoing vessels, etc.).

Fuel consumption and pollution emission studies in recent years have produced the data necessary to further divide the categories in Table A-1 according to usage. For example, the residential sector historically consumes gas for space heating (70%), water heating (21%), and cooking (7%), with the balance (2%) being used for clothes drying. Most other categories in Table A-1 lend themselves to similar analysis with data that are now available for energy usage. In addition, individual categories lend themselves to more detailed analysis in which major types of combustion equipment for each category are identified, e.g., the gas burned for residential space heating can be assessed to determine the extent to which different types of space heating equipment (hot air furnace, steam, hot water, and others) are employed.

In summary, it appears that except for the industrial sector, all sectors can be analyzed without unreasonable effort to develop combustion source inventories that are translatable into emission estimates. Most categories except industrial and utility will involve area sources. For the utility sector all plants with boilers greater than 50 MW in capacity will be treated as major point sources. This will involve investigating 400 to 500 plants for which extensive data are available from the Federal Power

TABLE A-1. FOSSIL FUEL BURNING BY CONSUMING SECTOR

Sector	Fuel	Quantity, 10^{12} Btu
Residential	Gas (natural and LPG)	5,511
	Oil (distillate and kerosene)	1,842
Commercial	Gas (natural and LPG)	2,917
	Oil (distillate)	574
	Oil (residual)	511
Transportation	Gas (natural and LPG)	619
	Oil (distillate)	2,858
	Motor gasoline	13,221
Electric utility	Gas (natural)	3,609
	Oil (light distillate and jet fuel)	288
	Oil (residual)	3,060
	Coal	11,263
Industrial	Gas (natural and LPG)	10,143
	Oil (distillate and kerosene)	1,883
	Oil (residual)	1,674
	Coal	3,702
	Total	63,675

Commission, hence, no problems in this connection are anticipated. Thus, the problems in assessing all fuel combustion are mainly those associated with the industrial sector.

APPROACH TO INDUSTRIAL ASSESSMENT

The many analyses of industrial energy consumption that have been conducted in recent years present data that are either broad and general (e.g., overall energy consumption for industry sectors) or provide background on only a part of the total problem (e.g., industrial boilers). The present study will be the first to take overall energy consumption by industry and divide it into segments for orderly analysis of the combustor population. The approach to be used is discussed briefly below, beginning with a discussion of fuel use data for 1977.*

Fuel Consumption by Fuel Type and Industry Group

All industrial consumption of fossil fuel amounted to about 17.7 x 10^{15} Btu in 1977. Consumption of electricity amounted to the fuel equivalent of about 7.0 x 10^{15} Btu, bringing the total industrial consumption to about 24.7 x 10^{15} Btu. This consumption is shown by fuel type and major industry group, as defined by the Standard Industrial Classification Manual (SIC's) in Table A-2. All values except those in the "Non-purchased fuels" column are from the 1977 Census of Manufacturers conducted by the Bureau of Census. Data for non-purchased fuels were supplied by industrial sources. Non-purchased fuels account for about 7.5 x 10^{15} Btu.

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* More recent data will be used for the study. 1977 data were used here for convenience.

TABLE A-2. FUEL AND ELECTRICITY USED IN MANUFACTURING

Industry		Electricity[a]	Distillate oil	Residual oil	Coal	Coke & Breeze	Natural gas	Other[b,c]	Sub-total	Non-purchased fuels	Total
20	Food and kindred	420.4	75.3	120.4	88.7	1.4	436.7	93.3 (82.4)	1236.2	-	1236.2
21	Tobacco	13.2	1.6	5.5	7.0[d]	-	2.4	-	29.7	-	29.7
22	Textiles	209.9	29.0	73.2	31.6	-	75.8	35.4 (33.5)	534.9	-	534.9
23	Apparel	69.5	4.5	4.2	1.8	-	15.6	16.9 (2.1)	112.5	-	112.5
24	Lumber and wood	169.6	33.6	15.3	17.9[d]	-	65.5	40.3 (40.3)	342.2	-	342.2
25	Furniture	43.7	5.3	2.8	2.9	-	18.4	9.1 (8.6)	82.2	-	82.2
26	Paper	486.1	33.4	472.8	226.9	-	358.4	64.3 (61.5)	1624.4	953[e]	2577.4
27	Printing	110.8	5.9	2.8	12.0[d]	-	29.1	6.5 (6.5)	167.1	-	167.1
28	Chemicals	1565.8	118.9	286.2	342.1	59.0[d,f]	1519.6	143.9 (143.9)	4035.0	2479[g]	6514.5
29	Petroleum	316.7	22.4	61.0	4.8	-	1076.2	12.9 (12.9)	1494.0	2176[h]	3670.0
30	Rubber	237.0	18.5	47.2	23.9	-	73.0	32.7 (28.1)	432.3	-	432.3
31	Leather	15.1	2.1	5.3	1.2	-	5.6	4.0 (3.8)	33.3	-	33.3
32	Stone, clay, glass	323.7	80.9	82.2	344.4	9.7	536.1	93.3 (75.8)	1470.3	-	1470.3
33	Primary metals	1656.2	72.5	259.6	135.4[i]	496.2	927.3	110.2 (106.0)	3657.4	1456.1	5113.5
34	Fabricated metals	277.3	27.2	22.2	10.8	1.6	188.7	54.7 (50.1)	582.5	-	582.5
35	Machinery	298.8	20.0	21.6	18.5	2.8	131.0	48.6 (44.2)	541.3	-	541.3
36	Electronics	262.2	16.1	15.2	14.3	0.3	86.4	31.8 (29.2)	426.3	-	426.3
37	Transportation	325.3	16.6	35.2	48.3	5.4	140.9	37.8 (36.2)	609.5	-	609.5
38	Instruments	58.2	3.4	9.3	25.8[d]	-	18.1	2.9 (2.9)	117.7	-	117.7
39	Miscellaneous	43.4	4.4	5.3	7.4[d]	-	15.1	2.8 (2.8)	78.4	-	78.4
	Total	6964.9	591.6	1547.3	1365.7	576.4	5719.9	841.9	17607.6	7064.1	20671.7

Note: All base numbers are from the Bureau of Census Annual Survey of Manufacturers, 1977, Part 1. Conversion factors are as follows: Coal - 26.194E6 Btu/ton; Coke - 25.993E6 Btu/ton; Residual oil - 6.285E6 Btu/bbl; Distillate oil - 5.824E6 Btu/bbl; Natural gas - 1024 Btu/ft^3; Other - 478E3 Btu/$.

[a] Electric quantities were converted from kWh to Btu by the factor 10500 Btu/kWh.

[b] Differences in reported fuels and the total Census quantities were adjusted in the "other" fuels column.

[c] Items in parenthesis represent the total as indicated by Census Data.

[d] Figure not reported by the Census; derived by difference.

[e] Byproduct fuel as reported by API (5).

[f] Actual reported coking coal use was 85 x 10^{12} Btu (6); assuming 70 percent conversion the coke consumption would be 59.5 x 10^{12} Btu.

[g] Feedstock as reported by Shell (6).

[h] Byproduct as reported by the Bureau of Census (8).

[i] Estimated by PEDCo, based on 1978 DOE data (7).

This includes byproduct fuels in the paper industry (953 x 10^{12} Btu), feedstocks for the chemical industry (2479 x 10^{12} Btu), byproduct fuels from petroleum refining (2176 x 10^{12} Btu), and coal for steelmaking (1952 x 10^{12} Btu).* These blocks of consumption represent uses that are for the most part well documented as far as process characteristics and location of facilities are concerned, hence, development of a source inventory from readily available data will be possible without undue difficulty. The balance of the industrial fuel-burning (purchased fuels in the amount of 10.6 x 10^{15} Btu) is documented in the Bureau of Census data in detail beyond that shown in Table A-2, and as discussed later, lends itself to orderly analysis of fuel use and associated pollution.

Strategy for Industrial Sector Analysis

The present project will result in a combustion source inventory that is comprehensive in that all significant consumers of fuel are identified and detailed from the standpoint of geographical distribution of fuel burning sources. To keep the effort involved in development of the inventory modest, a strategy for analysis has been developed and tested.

For the inventory all combustion sources will be ultimately divided into two types: "major point sources", that will be located specifically within individual counties and states, and "area sources", for which fuel consumption will be quantified by type on a county-by-county basis. This is the classic approach, and is consistent with the NEDS treatment, so that direct comparisons will be possible even though an independent approach will be used.

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* Includes coal consumed in making coke and byproduct fuels (1456 x 10^{12} Btu) and coke used to make steel (496 x 10^{12} Btu).

Major Point Sources--

A primary step in developing the inventory will be building the major point source data base. In the past few years a number of studies have provided new perspective on the hardware associated with industrial fuel burning. Studies of direct-fired processes have shown that some 19 major processes consume about 70 percent of the estimated 6.0×10^{15} Btu that goes into direct-fired processes (see Table A-3). Studies of the industrial boiler population produced a large body of information on the size, type, and location of the large industrial boilers. Taken together these studies have shown that the total number of processes that are major point sources is smaller than might have been expected and because many plants or facilities employ a number of processes, the different types of plants that must be considered is limited. For example, a petroleum refinery is a plant or facility that employs one or more of the eight individual refinery processes (atmospheric distillation, catalytic reforming, vacuum distillation, etc.) that have been shown to be in the group of 29 processes that consume almost 70 percent of all fuel burned in direct-fired processes. Table A-4 shows the type and approximate number of facilities that employ processes that can be considered to be major sources of sufficient importance to be given individual

TABLE A-3. SUMMARY OF MAJOR ENERGY CONSUMING DIRECT-FIRED PROCESSES

Industry	Process/Operation	10^{12} Btu/yr
Petroleum refining	Atmospheric distillation	529.3
Iron and steel	Slabbing and blooming - reheat furnaces (271.5) - soaking pit (156.3)	427.8
Petroleum refining	Catalytic reforming	407.1
Hydraulic cement	Calcining	324.5
Petroleum refining	Vacuum distillation	296.5
Iron and steel	Blast furnace	267.3
Petroleum refining	Coking (delayed)	266.2
Petroleum refining	Fluid bed catalytic cracker	229.2
Glass	Melting	227.2
Organic chemicals	Ethylene/propylene (thermal cracking)	194.5
Lime	Calcining	145.9
Iron and steel	Coking	144.8
Agricultural chemicals	Ammonia steam reforming	139.0
Petroleum refining	Gas/oil hydrotreating	119.9
Iron and steel	Heat treatment	111.5
Iron and steel	Steelmaking - open hearth furnace (71.8) - basic oxygen furnace (14.4)	86.2
Petroleum refining	Naphtha hydrotreating	77.8
Brick	Drying/firing	52.8
Organic chemicals	Benzene	44.8
Petroleum refining	Alkylation	42.8
Iron and steel	Cast iron melting - cupola furnace (21.7) - induction furnace (16.1)	37.8
Carbon black	Furnace process	35.7
Primary nonferrous metals	Copper smelting	34.7
Primary nonferrous metals	Alumina calcining	30.0
Total		4,273.3

TABLE A-4. TYPES OF MAJOR INDUSTRIAL FACILITIES AND APPROXIMATE NUMBER IN THE UNITED STATES

Industrial boilers (200-300)
Iron and steel plants (50)
Refineries (300)
Cement plants (150)
Major chemical plants (200)
Brick plants (465)
Glass plants (150)
Lime plants (150)
Primary nonferrous smelters (30)
Pulp mills (200)

attention in a combustion source inventory. Preliminary investigation shows that plants of the type shown in Table A-3 can be located geographically and that fuel consumption estimates can be developed for each. This investigation suggests also that while the list is likely to be modified as the study progresses, the changes are likely to be modest and incremental so that the present figures are a reasonable basis for planning.

Census of Manufacturers--

A second fundamental step in developing the inventory for major point sources involves analysis of the 450 "industries" defined by the Standard Industrial Classification Manual (SIC's). The SIC's collect data on number of establishments, number of employees, etc. as well as data on fuel consumption by type, and geographically by state, for each industry that is identified by a 4-digit code. These data provide a basis for classification of all industrial combustion sources as either point source or area sources. For purposes of analysis they can be divided into three groups. One is comprised of sixteen industries that employ major point source processes (e.g., 3321 - blast furnace and steel mills). Another involves over 300 industries that do not employ major point sources. The third is made up of 80 to 90 industries that will require some further analysis.

The SIC categories associated with major point sources consumed almost 50 percent of the industrial purchased fuel (4.8 x 10^{15} Btu/yr) in 1977. The balance of 5.8 x 10^{12} is consumed in over 400 SIC industry categories. Fortunately, analysis of the consumption can be simplified by eliminating over 300 industries in which individual establishments consume less than 100 x 10^9 Btu/yr.* Industries in this category include SIC categories such as 2016 - poultry dressing plants, 2451 - mobile homes, 3161 - luggage, 3444 - sheetmetal work, etc. The total fuel consumption for this group came to 2.3 x 10^{15} Btu in 1977. This limits the categories for further analysis to around 80 to 90 industries that consumed about 3.5 x 10^{12} Btu in 1977.

All the industries that consume over 100 x 10^9 Btu/establishment/year are shown in Table A-5. The data include those industries that are known to have large point sources (marked with an asterisk), in addition to the 80 to 90 that will be examined further. These data are suggestive of the kinds of analysis that will be required.

For industries such as cement, lime and brick, etc., that are known to be associated with major point sources, it appears that the major processes involved represent most of the fuel consumption, thus simplifying the analysis. Glass comparisons are slightly more complicated in that the 4-digit industries reflect statistics for different product types. The data for iron and steel apparently reflect exclusion of reductant coke for blast furnaces from the purchased fuel report, while the data for petroleum refining reflects the refinery use of byproduct fuels not covered by the purchased fuel report.

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* This is the equivalent of the heat input to a very small boiler (2-3 MW equivalent) operated about half time. This limit eliminated over 300 categories and was felt to be low enough to prevent missing a few large sources in industries with a large number of facilities.

TABLE A-5. STANDARD INDUSTRIAL CLASSIFICATION CODES WITH CONSUMPTION OF FOSSIL FUELS GREATER THAN 100 x 10^9 Btu PER YEAR

	Average 1977 consumption per establishment, 10^9 Btu	
	All establishments	Establishments with 20 or more employees
SIC 20 - Food and kindred products		
2023 - Condensed and evaporated milk	88.7	159.4
2032 - Canned specialties	84.7	195.4
2034 - Dehydrated fruits, vegetables, and soups	72.8	154.0
2037 - Frozen fruits and vegetables	104.2	140.4
2043 - Cereal breakfast foods	170.8	234.2
2046 - Wet corn milling	2,023.0	2,922.2
2061 - Raw cane sugar	189.2	223.6
2062 - Cane sugar refining	802.5	1,188.8
2063 - Beet sugar	1,294.7	1,419.2
2066 - Chocolate and cocoa products	64.2	133.3
2075 - Soybean oil mills	334.7	465.5
2076 - Vegetable oil mills, N.E.C.[a]	47.6	105.2
2077 - Animal and marine fats and oils	54.2	134.8
2079 - Shortening and cooking oils	229.3	312.5
2082 - Malt beverages	329.7	474.7
2083 - Malt	210.0	311.1
2085 - Distilled liquor, except brandy	139.4	188.3
SIC 21 - Tobacco products		
2111 - Cigarettes	750.0	807.6
SIC 22 - Textile mill products		
2211 - Weaving mills, cotton	66.8	109.3
2261 - Finishing plants, cotton	116.6	260.6
2262 - Finishing plants, synthetics	148.0	223.2
2272 - Tufted carpets and rugs	61.6	110.3
2296 - Tire cord and fabric	125.0	125.0

(continued)

TABLE A-5 (continued)

	Average 1977 consumption per establishment, 10^9 Btu	
	All establishments	Establishments with 20 or more employees
SIC 24 - Lumber and wood products		
2436 - Softwood veneer and plywood	99.6	113.8
2492 - Particleboard	87.3	107.8
SIC 26 - Paper and allied products		
2611 - Pulp mills	1,882.2	2,016.6
2621 - Paper mills, except building paper	1,518.8	1,794.0
2631 - Paperboard mills	1,792.3	1,923.7
2661 - Building paper and board mills	444.8	486.7
2646 - Pressed and molded pulp goods	150.0	211.1
SIC 28 - Chemicals and allied products		
2812 - Alkalies and chlorine	1,795.9	2,666.6
2813 - Industrial gases	54.4	300.0
2816 - Inorganic pigments	389.6	625.7
2819 - Industrial inorganic chemicals, N.E.C.	409.3	801.7
2821 - Plastic materials and resins	381.1	488.0
2822 - Synthetic rubber	619.0	1,300.0
2823 - Cellulosic manmade fibers	5,670.0	5,670.0
2824 - Organic fibers, noncellulosic	1,850.0	2,105.1
2833 - Medicinals and botanicals	141.8	330.2
2834 - Pharmaceutical preparations	39.8	102.7
2841 - Soap and other detergents	35.7	100.8
2843 - Surface active agents	49.7	103.5
2861 - Gum and wood chemicals	79.8	256.7
2865 - Cyclic crudes and intermediates	795.8	1,196.8
2869 - Industrial organic chemicals, N.E.C.	1,784.7	2,934.9
2873 - Nitrogenous fertilizers	1,538.1	2,656.8
2874 - Phosphatic fertilizers	583.5	769.5
2879 - Agricultural chemicals, N.E.C.	57.4	194.2
2892 - Explosives	158.7	290.5
2895 - Carbon black	877.4	877.4
2899 - Chemical preparations, N.E.C.	32.4	138.5

(continued)

TABLE A-5 (continued)

	Average 1977 consumption per establishment, 10^9 Btu	
	All establishments	Establishments with 20 or more employees
SIC 29 - Petroleum refining and related industries		
2911 - Petroleum refining	3,225.5	4,034.7
2951 - Paving mixtures and blocks	32.7	203.0
2952 - Asphalt felts and coatings	103.6	173.7
2999 - Petroleum and coal products, N.E.C.	104.2	317.3
SIC 30 - Rubber and miscellaneous plastic products		
3011 - Tires and inner tubes	324.0	514.2
3041 - Rubber and plastic hose and belting	76.7	108.7
SIC 32 - Stone, clay, glass, and concrete products		
3211 - Flat glass	893.5	1,731.2
3221 - Glass containers	1,022.2	1,038.7
3229 - Pressed and blown glass, N.E.C.	157.5	481.6
3241 - Cement, hydraulic	2,087.0	2,621.8
3251 - Brick and structural clay tile	190.3	255.7
3253 - Ceramic wall and floor tile	79.7	131.2
3255 - Clay refractories	118.5	190.3
3259 - Structural clay products, N.E.C.	155.7	308.7
3261 - Vitreous plumbing fixtures	115.7	213.1
3262 - Vitreous china food utensils	100.0	200.0
3263 - Fine earthenware food utensils	82.6	111.7
3274 - Lime	1,014.8	1,514.2
3275 - Gypsum products	339.8	537.0
3292 - Asbestos products	61.7	100.0
3295 - Minerals, ground or treated	64.5	199.3
3296 - Mineral wool	305.2	518.8
3297 - Nonclay refractories	145.8	240.9
3299 - Nonmetallic mineral products, N.E.C.	10.9	108.5

(continued)

TABLE A-5 (continued)

	Average 1977 consumption per establishment, 10^9 Btu	
	All establishments	Establishments with 20 or more employees
SIC 33 - Primary metal industries		
3312 - Blast furnaces and steel mills	2,696.4	5,436.0
3316 - Cold finishing of steel shapes	94.1	155.3
3317 - Steel pipe and tubes	98.3	124.6
3321 - Gray iron foundries	98.6	142.1
3322 - Malleable iron foundries	178.7	222.6
3325 - Steel foundries, N.E.C.	73.0	103.0
3331 - Primary copper	2,211.1	2,211.1
3332 - Primary lead	1,671.4	1,671.4
3333 - Primary zinc	2,700.0	3,085.7
3334 - Primary aluminum	3,334.3	3,334.3
3339 - Primary nonferrous metals, N.E.C.	224.7	734.6
3341 - Secondary nonferrous metals	74.3	171.0
3351 - Copper rolling and drawing	129.2	182.8
3353 - Aluminum sheet, plate, and foil	1,096.2	1,291.1
3354 - Aluminum extruded products	89.1	117.8
3355 - Aluminum rolling and drawing, N.E.C.	290.9	426.6
3356 - Nonferrous rolling and drawing, N.E.C.	51.7	103.4
SIC 34 - Fabricated metal products, except machinery and transportation equipment		
3431 - Enameled iron and metal sanitary ware	51.4	140.5
3462 - Iron and steel forgings	121.2	187.8
3463 - Nonferrous forgings	104.2	158.0
3482 - Small arms ammunition	47.6	193.7
3483 - Ammunitions, except small arms, N.E.C.	72.8	120.4
3489 - Ordance and accessories, N.E.C.	49.4	107.3

(continued)

TABLE A-5 (continued)

	Average 1977 consumption per establishment, 10^9 Btu	
	All establishments	Establishments with 20 or more employees
SIC 35 - Machinery, except electrical		
3511 - Turbines and turbine generator sets	78.5	173.6
3519 - Internal combustion engines, N.E.C.	71.1	125.9
3562 - Ball and roller bearings	79.8	114.4
3599 - Machinery, except electrical, N.E.C.	101.9	183.3
SIC 36 - Electrical and electronic machinery, etc.		
3624 - Carbon and graphite products	133.7	206.2
3631 - Household cooking equipment	53.1	204.0
3632 - Household refrigerators and freezers	233.3	392.0
3633 - Household laundry equipment	200.0	258.3
3639 - Household appliances, N.E.C.	66.2	132.5
SIC 37 - Transportation equipment		
3711 - Motor vehicles and car bodies	283.8	768.0
3721 - Aricraft	103.4	245.9
3764 - Space propulsion units and parts	119.2	134.7
3743 - Railroad equipment	63.6	108.4
3795 - Tanks and tank components	120.8	161.1
SIC 38 - Measuring, analyzing, etc.		
3861 - Photographic equipment and supplies	43.7	129.2
SIC 39 - Miscellaneous manufacturing industries		
3996 - Hard surface floor coverings	147.6	238.4

[a] N.E.C. = not elsewhere classified.

Other categories where major point sources have not yet been assessed will also present a variety of problems. Some, such as those categories involving foundries, are known to be classifiable as major point sources when they are large, but probably are not when they are small. These will require a significant amount of study for classification. Others, such as those in Major Group 20 - Food and Kindred Products, are expected to be dropped after cursory investigation confirms major point sources are not employed in their operations. It is felt, however, that in all situations known sources of information, or other readily available sources, will be adequate for the necessary evaluations.

In summary, the analysis of Census data will permit systematic identification of all direct-fired processes employed by industry* that should be classified as major point sources. Boilers, as indicated earlier, will be handled separately.

Industrial Boilers--

Because of the large amount of past work to characterize the large industrial boiler population, they will be analyzed using data bases that have been developed for other purposes. Past studies have shown that about 200 to 300 industrial boilers have heat input greater than that for a 50-MW utility boiler. While the procedures for handling large boilers as major point sources have not been developed, it appears, considering the known data base available and the limited number of facilities involved, that large boilers can be assessed to the same level of detail as direct-fired processes.

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* Only those SIC codes associated with manufacturing will be assessed. All of industrial consumption also includes consumption in agriculture and mining, but the relative amounts are small and major point sources are not involved.

SUMMARY AND CONCLUSIONS

In summary the methodology described involves the following steps:

First, the total fossil fuel consumption for all consuming sectors is quantified.

Consumption in the residential, commercial, and transportation sectors is assessed using conventional methodology for area sources.

Consumption in the utility sector is assessed using extensive documentation that is available.

Fuel use in agriculture, construction and mining (classified as industrial) will be assessed as area source consumption using conventional methodology. This reduces the fuel use to be assessed to the manufacturing sector.

The balance of the consumption in the industrial sector is assessed as subcategories involving use of fuel in: 1) boilers, 2) direct-fired processes, and 3) miscellaneous.

Non-purchased fuel use in manufacturing (byproduct fuels in papermaking and petroleum refining) is well documented and will be assessed using easily available data.

Purchased fuel use in manufacturing sector is documented in the Census of Manufacturing, which presents data for 450 industries as defined by the Standard Industrial Classification Codes. Most of these can be eliminated on the basis of insignificant fuel consumption per establishment per year.

Industrial boilers are assessed independently utilizing existing data bases, even though they are associated with the use of both non-purchased and purchased fuels.

The fuel consumption for analysis is thus reduced to a remaining small fraction (about 5%) of the annual fossil fuel consumption in the U.S. This is further reduced by assessment of some 16 SIC industries known to have major point sources that can be assessed using demonstrated methodology.

The remaining 80 to 90 SIC industries are reviewed to identify additional combustors that should be classified as major point sources.

Additional point sources are analyzed as such. Categories with no major point sources are grouped with those eliminated on the basis of low consumption and treated as area sources.

The above procedure systematically reduces the fossil fuel consumption to units that lend themselves to the kind of analysis that is needed for complete coverage of al fossil fuel consumption in the U.S. to produce a complete inventory of major point sources without excessive effort.

The inventory to be developed will be complete from the standpoint of identification and location of major point sources and area source fuel consumption. Fuel consumption estimates for major point sources will be developed from open literature and will provide reasonable approximations for initial inventory purposes.

The inventory will be analagous to the NEDS system and will, as far as possible, utilize NEDS data to supplement data from the open literature. In addition, the inventory will be used to make comparisons that will identify the strengths and weaknesses of both approaches.

APPENDIX B

FUEL CONSUMPTION METHODOLOGIES FOR DIRECT-FIRED SOURCES AND INDUSTRIAL BOILERS

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Introduction

Part 1 of this appendix provides a brief description of the methodology used in estimating fuel consumption and NO_x emissions for each of the 20 major industrial point source facility types present in the 150-county study area. Part 2 presents the industrial boiler methodology. Area source methodologies were covered in Section 3 of the text.

Each methodology discusses direct-fired processes of interest, plant capacity and production, energy use per unit of product, fuel type, and NO_x emission factors.

In general, an attempt was made to find the most accurate, up-to-date, and site-specific data for each methodology. For some industry types, less specific data had to be used because of budget and time restraints. These estimates could be refined at a later date.

PART 1

DIRECT-FIRED INDUSTRIAL POINT SOURCES

INDUSTRY: PETROLEUM REFINING

PLANT/FACILITY: REFINERY

Direct-fired energy within a petroleum refinery is consumed in the following processes: atmospheric distillation, vacuum distillation, thermal operation, catalytic cracking, catalytic reforming, hydrocracking, hydrorefining, hydrotreating, alkylation, and aromatics manufacture (benzene, toluene, and xylenes). In each case, process heaters account for the direct-fired energy consumption. Crude capacity and/or charge capacity for each process was obtained from the Department of Energy's Energy Data Report.[1] Since the capacity was in barrels per stream day (bbl/sd), the days of operation per year were factored in to provide an annual production rate. A 90 percent capacity factor was used to calculate the number of operating days.[2] This is an industry-wide factor based on 1980 estimates; it is neither site-specific nor process-specific. Unit energy consumption (Btu/ton) factors were obtained from the Oil and Gas Journal.[3] Table B-1 illustrates the methodology used to estimate energy consumption for this industry. This table presents pertinent operating and energy consumption data for Ashland Oil's plant located in Buffalo, New York.

In the petroleum refining industry, the type of fossil fuel consumed by process heaters varies from region to region and

TABLE B-1. PERTINENT OPERATING AND ENERGY CONSUMPTION DATA FOR ASHLAND OIL PLANT AT BUFFALO, NEW YORK

	Atmospheric distillation	Vacuum distillation	Thermal operation	Catalytic cracking	Catalytic reforming	Hydro-cracking	Hydro-refining	Hydro-treating	Alkylation	Aromatics manufacture
Crude capacity, bbl/sd	64,000	28,000	0	22,000	11,000	0	15,200	11,000	2,000	6,200
Days of operation, sd/yr	330	330	330	330	330	330	330	330	330	330
Energy consumption, 10^3 Btu/bbl	103	125	300	113	314	333	57	85	336	600
Annual total consumption, 10^{12} Btu/yr	2.18	1.16	0	0.82	1.14	0	0.29	0.31	0.22	1.23

often from plant to plant. The availability of specific fuels is a major factor in determining the ratio of oil and gas. On an industry-wide basis the breakdown of fuel types consumed in process heaters is shown below:[4]

CO gas	Natural gas	Refinery gas	Residual oil
1.1%	24.9%	68.5%	5.5%

The NO_x emission factors selected for process heaters are shown in Table 3-4. The NO_x emission factors for oil and gas are 55 $lb/10^3$ gal and 140 $lb/10^6\ ft^3$, respectively.[5] It has been assumed that NO_x emissions from refinery gas and CO gas are the same as NO_x emissions resulting from the combustion of natural gas in process heaters.

REFERENCES

1. U.S. Department of Energy. Energy Data Report - Petroleum Refineries in the United States and U.S. Territories, Washington, D.C. 1981.

2. U.S. Department of Energy. Trends in Capacity and Utilization. Petroleum Refineries in the United States - Foreign Refinery Exporting Centers. Washington, D.C. 1981.

3. Nelson, W. L. What Are Utility Needs? Oil and Gas Journal, 75(45):118-119, 1977.

4. Cherry, S. S. Draft Emissions Control by Advanced Combustion Modification Techniques for Industrial Combustion Equipment Task 1 - Equipment Survey. Research Triange Park, N.C. EPA 68-02-3690, 1982.

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INDUSTRY: PETROCHEMICALS

PLANT/FACILITY: AMMONIA PLANTS

Chemical and Engineering News estimated 1981 ammonia production as 19,200,000 tons.[1] U.S. capacity for 1981 was estimated at approximately 20,122,000 tons.[2] Based on these data, the calculated percent capacity utilization factor is 90 percent for 77 ammonia plants in 1981.[2]

Plant-specific production is estimated by multiplying plant capacity times the percent capacity utilization. The unit energy consumption attributed to the tubular furnace is estimated to be 16.1×10^6 Btu/ton.[3] Natural gas is the primary fuel consumed by the direct-fired furnace.

Table 3-4 presents the emission factor used to estimate NO_x emissions in this industry. The tubular furnace emits approximately 5.8 lb/ton.[4]

REFERENCES

1. Kiefer, D. M. Chemical Output is Sliding Following a Short-Lived Recovery. Chemical and Engineering News, 59(51):32-41, December 21, 1981.

2. SRI International. 1982 Directory of Chemical Producers, United States of America. Menlo Park, California. 1982.

3. Energy and Environment, Inc. The Technical Feasibility of Coal Use in the Industrial Process Heat Application. Prepared for the Department of Energy, Washington, D.C. 1978.

4. U.S. Environmental Protection Agency. Compilation of the Air Pollutant Emission Factors. 3rd Edition (including Supplements 1 through 13, Final). Research Triangle Park, North Carolina. AP-42. 1977.

INDUSTRY: PHOSPHATE ROCK AND BASIC FERTILIZER

PLANT/FACILITY: SODIUM PHOSPHATES

Sodium phosphates are most commonly made from phosphoric acid and soda ash. Products include both ortho- and polyphosphates. The former category includes mono-, di-, and trisodium phosphates, and the latter includes sodium tripolyphosphate, tetrasodium pyrophosphate, sodium metaphosphate, and sodium acid pyrophosphate. Only the manufacture of polyphosphates entails the use of direct-fired fossil fuel. Figure B-1 is a simplified flow sketch of the manufacturing process for crystalline sodium polyphosphates.[1] The process for the manufacture of sodium hexametaphosphate or "glassy phosphate," which comprises the majority of metaphosphate made, is somewhat different in that the mixed mono- and disodium phosphate solution occurring from phosphoric acid and soda ash reaction is not dried but fed directly to a fusion furnace and cooled to form the "glassy phosphate."

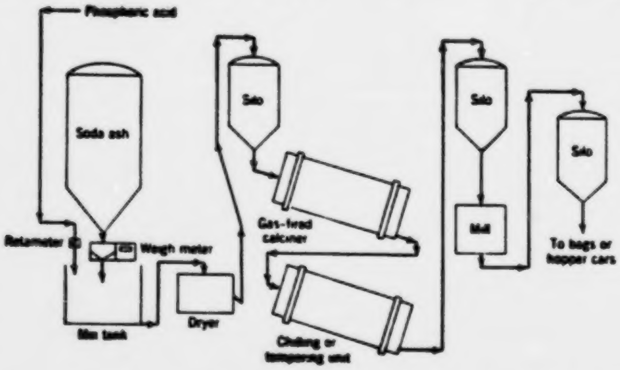
Phosphoric acid
Soda ash
Rotameter
Weigh meter
Mix tank
Dryer
Silo
Gas-fired calciner
Chilling or tempering unit
Silo
Mill
Silo
To bags or hopper cars

Figure B-1. Manufacture of crystalline sodium polyphosphates.

The study area contains only two polyphosphate manufacture facilities, which have a combined annual capacity of 135 thousand tons (1981) of product.[2] Commodities produced between the two include sodium tripolyphosphate, tetrasodium pyrophosphate, sodium metaphosphate, and trisodium phosphate (chlorinated). The production of the latter material was assumed to be minimal. Production data were determined per facility by assuming 67 percent capacity production[3] and through use of the following 1980 industry-wide production data:[4]

	Short tons
Sodium acid pyrophosphate	28,953
Monosodium phosphate	43,687
Disodium phosphate	28,552
Trisodium phosphate	62,786
Tetrasodium pyrophosphate	30,772
Sodium metaphosphate	60,985
Sodium tripolyphosphate	727,440
Other[a]	Suppressed (confidential)
	983,175

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[a] "Other" includes certain chemicals, e.g., aluminum and chlorinated sodium phosphates of limited production.

For Monsanto's Kearny, New Jersey, facility, which produces only sodium tripoly- and metaphosphate at an annual capacity of 110,000 tons, it was possible to use the ratio of tripoly- to metaphosphate (U.S. Department of Commerce data) manufacture to estimate 1981 production at 68,031 tons and 5,669 tons per year, respectively.[2,3,4] For Stauffer's Morrisville, Pennsylvania facility (capacity 25,000 tons),[2] similarly derived estimated production was 11,167 tons of sodium metaphosphate and 5,583 tons of tetrasodium pyrophosphate.[3,4]

Energy-dependent equipment employed in polyphosphate manufacture include dryers, a rotary calciner, and a fusion furnace/kiln. Direct-firing of equipment is performed using either natural gas or oil. Energy consumption was determined per manufactured commodity at each facility as follows:

Dryer	3.6 x 10^6 Btu/ton[5]
Rotary kiln	5.05 x 10^6 Btu/ton[5]
Fusion furnace	7.2 x 10^6 Btu/ton[5] (sodium metaphosphate)

The energy value presented for drying represents spray drying. Energy consumption for each plant is as follows:

MONSANTO INDUSTRIAL CHEMICALS COMPANY

Sodium tripolyphosphate

Cryst/dry (68,031 tons)(3.6 x 10^6 Btu/ton)[8] = 0.245 x 10^{12} Btu

Calcination ((68,031 tons)(5.05 x 10^6 Btu/ton)[8] = 0.344 x 10^{12} Btu

Sodium metaphosphate

Fusion (5,669 tons)(7.2 x 10^6 Btu/ton)[8] = 0.041 x 10^{12} Btu

STAUFFER CHEMICAL COMPANY

Tetrasodium pyrophosphate

Cryst/dry (5,583 tons)(3.6 x 10^6 Btu/ton)[8] = 0.020 x 10^{12} Btu)

Calcination (5,583 tons)(5.05 x 10^6 Btu/ton)[8] = 0.028 x 10^{12} Btu

Sodium metaphosphate

Fusion (11,167 tons)(7.2 x 10^6 Btu/ton)[8] = 0.080 x 10^{12} Btu

Nitrogen oxide emissions were determined in the same manner (i.e., per commodity per plant) by using energy consumption for pertinent equipment and emission factors of 0.085 lb/10^6 Btu[6] for drying and 0.033 lb/10^6 Btu[6] for kilns. The following is a breakdown of NO_x emissions by plant and process/equipment:

MONSANTO INDUSTRIAL CHEMICALS COMPANY

Sodium tripolyphosphate

$$\text{Cryst/dry}\ \frac{(245{,}000 \times 10^{6}\ \text{Btu})(0.085\ \text{lb}/10^{6}\ \text{Btu})\,\text{[9]}}{(2000\ \text{lb/ton})} = 10.41\ \text{tons}$$

$$\text{Calcination}\ \frac{(344{,}000 \times 10^{6}\ \text{Btu})(0.033\ \text{lb}/10^{6}\ \text{Btu})\,\text{[9]}}{(2000\ \text{lb/ton})} = 5.68\ \text{tons}$$

Sodium metaphosphate

$$\text{Fusion}\ \frac{(41{,}000 \times 10^{6}\ \text{Btu})(0.033\ \text{lb}/10^{6}\ \text{Btu})\,\text{[9]}}{(2000\ \text{lb/ton})} = 0.68\ \text{tons}$$

STAUFFER CHEMICAL COMPANY

Tetrasodium pyrophosphate

$$\text{Cryst/dry}\ \frac{(20{,}000 \times 10^{6}\ \text{Btu})(0.085\ \text{lb}/10^{6}\ \text{Btu})\,\text{[9]}}{(2000\ \text{lb/ton})} = 0.85\ \text{tons}$$

$$\text{Calcination}\ \frac{(28{,}000 \times 10^{6}\ \text{Btu})(0.033\ \text{lb}/10^{6}\ \text{Btu})\,\text{[9]}}{(2000\ \text{lb/ton})} = 0.46\ \text{tons}$$

Sodium metaphosphate

$$\text{Fusion}\ \frac{(80{,}000 \times 10^{6}\ \text{Btu})(0.033\ \text{lb}/10^{6}\ \text{Btu})\,\text{[9]}}{(2000\ \text{lb/ton})} = 1.32\ \text{tons}$$

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1. Wazer, J. R. Phosphoric Acids and Phosphate. In: Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Vol. 15:232-276.

2. SRI International. 1982 Directory of Chemical Producers, U.S.A. Menlo Park, California. 1982.

3. Personal communication from SRI International, Menlo Park, California to T. Bertke, PEDCo Environmental, Inc., September, 1982.

4. Personal communication from J. Dodds, U.S. Department of Commerce to T. Bertke, PEDCo Environmental, Inc., September 16, 1982.

5. Muehlberg, P. E., et al. Industrial Process Profiles for Environmental Use. Chapter 22. The Phosphate Rock and Basic Fertilizer Industry. U.S. Environmental Protection Agency/IERL, Cincinnati, Ohio. EPA-600/2-77-0234. February, 1977.

6. Mills, J. L., et al. Emissions of Oxides of Nitrogen from Stationary Sources in Los Angeles County. Los Angeles County Air Pollution Control District, Los Angeles, California, July, 1961.

INDUSTRY: PULP AND PAPER

PLANT/FACILITY: KRAFT PULP MILLS

The only significant direct-fired process in kraft pulp mills is the regeneration of lime in kilns. Production capacity for each plant is generally available.[1] Estimated production can be obtained by multiplying capacity times the number of operating days. Generally, pulp mills operate about 348 days per year.[2]

Total energy consumption for the entire pulp mill industry has been estimated at 18 x 10^6 Btu/ton of pulp.[3] Most of the energy consumed at kraft pulp mills is for the production of steam in boilers.

Lime kilns generally consume 8.58 x 10^6 Btu/ton of lime.[4,5] This direct-fired process represents approximately 12 percent of the total energy consumed at a pulp mill.

These kilns are generally fired with natural gas or oil.[6] The type of fuel(s) consumed by the plant are generally reported,[1] and although this inormation is not specific to the lime kiln, the reported fuel is used in this methodology. When two fuels, such as natural gas and sawdust, are reported, natural gas would be considered the primary fuel fired in each kiln.

Table 3-4 presents the NO_x emission factor used for this industry. The lime kiln emits approximately 3.0 lb/ton of lime, which equates to about 1 lb/ton of pulp.[7]

REFERENCES

1. 1981 Post's Pulp and Paper Directory. Miller Freeman Publications, Inc., San Francisco, California.

2. Personal communication from P. Thorton, Miller Freeman Publications, Inc., to M. Taft-Frank, PEDCo Environmental, Inc., March 1982.

3. Institute of Gas Technology. Study of Industrial Uses of Energy Relative to Environmental Effects. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. July 1974.

4. U.S. Environmental Protection Agency. Environmental Pollution Control. Pulp and Paper Industry. Part 1. Air. EPA-625/7-76-001, October 1976.

5. PEDCo Environmental, Inc. Feasibility of Destroying Hazardous Waste in High Temperature Processes. EPA 68-03-3036, May 1982.

6. Roy F. Weston, Inc. Energy Requirements for Environmental Control in the Pulp and Paper Industry. West Chester, Pennsylvania. Ma_ch 1977.

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INDUSTRY: GYPSUM

PLANT/FACILITY: GYPSUM PLANTS

Calcined gypsum is used in prefabricated products (e.g., wallboard) and as a plaster. The calciner is the major direct-fired equipment used in this industry.

Site-specific data on gypsum plants are not readily available. Plant production is not given, but approximate production can be estimated. By using 1980 Bureau of Mines (BOM) data, one can estimate national and regional production.[1] The BOM data indicate that the top 10 plants accounted for 27 percent of the national output and that the top 5 companies (operating 60 plants) accounted for 80 percent of the national output.[1] Extrapolation of the above data can provide approximate plant production. This methodology could be further refined by using Shipment Reports from Economic Information Systems, Inc., which provides each plant's share of the market.[2]

The gypsum calciner consumes 0.75×10^6 Btu/ton,[3] and natural gas is its primary fuel.[1]

Table 3-4 presents the NO_x emission estimate methodology applied to the gypsum calciner. A specific NO_x emission factor for calcining gypsum was not available so emissions were estimated by using the graph shown in Figure 3-4.[4]

REFERENCES

1. U.S. Department of the Interior. Minerals Yearbook. Volume 1. Metals and Minerals. Bureau of Mines, Washington, D.C. 1980.

2. Economic Information Systems, Inc. Shipments Report. SIC 3275 - Gypsum. New York. 1982.

3. Personal communication from J. Pressler, Bureau of Mines to M. Taft-Frank, PEDCo Environmental, Inc., August 1982.

4. Mills, J. L., et al. Emissions of Oxides of Nitrogen from Stationary Sources in Los Angeles County. Report No. 4. Prepared for the Los Angeles County APCD, Los Angeles, California. 1961.

INDUSTRY: LIME

PLANT/FACILITY: LIME PLANT

Lime is calcined in a direct-fired kiln, which is the only significant direct-fired equipment in the lime industry. Site-specific data on lime plants are not readily available, but approximate national and regional production can be estimated by using 1980 Bureau of Mines data. These data indicate that the top 10 plants in the United States accounted for 32 percent of the total lime produced in 1980.[1] Another Bureau of Mines reference states that the top 10 companies (operating 33 plants) accounted for 47 percent of the 1980 production.[2] A final production clue relates to the number of plants in various size classes. For instance, Reference 2 states that only seven plants produce more than 400,000 tons per year. Knowing 1) the top 10 producing plants, 2) the top 10 producing companies, 3) the regional production, and 4) the number of plants within various size classes makes it possible to estimate approximate production. This methodology could be further refined by using the Economic Information Systems, Inc. (EIS) Shipments Report, which provides each plant's share of the market.[3]

On the average, lime kilns consume approximately 8.58×10^6 Btu/ton.[2,4] Reportedly, 1980 purchased fuels for the commercial lime industry were 68.2 percent coal and coke, 25.4 percent natural gas, 4.02 percent oil (No. 6 and No. 2), and 2.4 percent other.[2] Depending on kiln design, a plant may use coal or a combination of fuels such as coal and natural gas.

Table 3-4 presents the NO_x emission factor applied to the lime kiln. The NO_x emission factor applied to lime kilns was 3.0 lb/ton.[5]

REFERENCES

1. U.S. Department of the Interior. Mineral Industry Surveys. Lime Plants in the United States 1980. Bureau of Mines, Washington, D.C. 1981.

2. U.S. Department of the Interior. Preprint from the 1980 Bureau of Mines Minerals Yearbook - Lime. Bureau of Mines, Washington, D.C. 1981.

3. Economic Information Systems, Inc. Shipments Report. SIC 3274 - Lime. New York, 1982.

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5. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. 3rd Edition (including Supplements 1 through 13, Final). Research Triangle Park, North Carolina. AP-42, 1977.

INDUSTRY: CLAY PRODUCTS

PLANT/FACILITY: BRICK AND TILE PLANTS

In 1977, approximately 293 plants produced 4.24×10^7 tons of structural brick and clay tile.[1,2] Because detailed data are not available for this industry, a number of assumptions had to be made to estimate fuel consumption and NO_x emissions.

Plant capacity and production for all U.S. plants are considered proprietary; therefore, these data are extremely difficult to obtain. In lieu of plant-specific data, U.S. production was estimated and apportioned to each plant based on its share of the U.S. market.

Estimates of U.S. production data were based on the 1977 Census of Manufactures.[2] Unfortunately, not all subcategories within the brick and tile industry reported production. If available, 1972 production data were substituted for missing 1977 data. The subcategories for which no data could be located appeared to be small (based on their product value), so they were not included in the total U.S. production estimate.

Apportioning total U.S. production to an industrial plant was accomplished by using the EIS report on shipments.[1] This report estimates each company's shipments and its share (based on shipments) of the U.S. market. Assuming that each company's market share (of total U.S. shipments) is directly equatable with production, this share or percentage can be used to apportion U.S. total production to plant-specific production.

This industry uses two basic types of kilns, the continuous energy-efficient tunnel kiln and the older batch periodic kiln. Estimates indicate that tunnel kilns consume approximately 2.4 x 106 Btu's/ton.[3] Periodic kilns consume from two to five times as much and are in the process of being phased out at the larger more mechanized plants. The periodic kilns, however, are necessary for production of certain types of specialty brick, and are still used on a routine basis by smaller specialty plants. A generalized energy consumption factor of 3.5 x 106 Btu/ton was used in the energy calculations.[4] This estimate represents an average fuel consumption, regardless of kiln type. Natural gas is the predominant fuel fired in these kilns.[5] Generally, a kiln will burn one type of fuel; newer kilns have a dual fuel design. For this study, it has been assumed that natural gas is the only fuel fired.

A weighted NO_x emission factor of 0.23 lb/ton was based on an estimated 65 percent tunnel and 35 percent periodic kiln production.[6]

REFERENCES

1. Economic Information Systems, Inc. Shipments Report. SIC 3251 - Brick and Structural Clay Tile. New York, 1982.

2. U.S. Department of Commerce. 1977 Census of Manufacturers. Industry Series. Bureau of the Census. 1980.

3. Battelle Columbus Laboratories. Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing. Prepared for the Bureau of Mines, June 1975.

4. Personal communication from J. Blazina, Swindal Rust, to M. Taft-Frank, PEDCo Environmental, Inc., 1981.

5. Personal communication from N. Farley, Brick Institute of America to M. Taft-Frank, PEDCo Environmental, Inc., March 1982.

6. Battelle Columbus Laboratories. The Cost of Clean Air and Water Reports to Congress. Prepared for the U.S. Environmental Protection Agency, Washington, D.C. 1979.

INDUSTRY: CLAY PRODUCTS

PLANT/FACILITY: LIGHTWEIGHT AGGREGATE

Lightweight aggregates encompass a variety of raw materials used to provide bulk in concrete. Based on direct-fired energy estimates, only the manufacture of expanded clay, shale, and slate in rotary kilns meets the established energy consumption criteria selected for this study.

In 1981, 36 domestic plants manufactured approximately 3.65 million tons of lighweight aggregates.[1] The production capacity of a typical lightweight aggregate rotary kiln operating 260 days per year is 500 tons per day.[2] Industry experts estimate plants are currently utilizing 50 percent of their capacity.[3]

Because competition is severe between plants in this industry, there is a reluctance to release capacity or production data.[4,5] Plant-specific production or capacity data are rarely available. An extensive literature search to obtain these data involved contacting the following sources for information:

- The Bureau of Mines
- The Expanded Shale, Clay, and Slate Institute
- The Lightweight Aggregate Producers Association
- Rock Products

- Pit and Quarry
- State and local regulatory agencies

Capacity data were obtained for Norlite Corporation, the only plant in the study area.[6] Production was estimated by multiplying capacity times percent utilization. This method of estimating production could be refined by using Economic Information Systems, Inc., Shipments Report for SIC 3295 Minerals, Ground or Treated.

Generally, the lightweight aggregate kiln consumes approximately 2.6×10^6 Btu/ton of aggregate.[2] Coal is the predominant fuel consumed in this industry, although some kilns are designed to fire natural gas, fuel oil or a combination of these two.[2]

The NO_x emission factor selected was 3.0 lb/ton. Little published information exists on emissions from lightweight aggregate rotary kilns. Based on the similarities in temperature, equipment type, and predominant fuel, the NO_x emission factor for a lime rotary kiln was applied.

REFERENCES

1. Personal communication from H. Robinson, Expanded Shale, Clay and Slate Institute, to M. Taft-Frank, PEDCo Environmental, Inc., October 1982.

2. PEDCo Environmental, Inc. Feasibility of Destroying Hazardous Waste in High-Temperature Industrial Processes. EPA 68-03-3036, May 1982.

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4. Personal communication from T. Kuennen, Rock Products, to M. Taft-Frank, PEDCo Environmental, Inc., September 1982.

5. Personal communication from J. Kostka, Pit and Quarry Publications, Inc., to M. Taft-Frank, PEDCo Environmental, Inc., September 1982.

6. Personal communication from B. Pearson, Department of Health, County of Albany, to M. Taft-Frank, PEDCo Environmental, Inc., August 1982.

INDUSTRY: CEMENT

PLANT/FACILITY: CEMENT PLANTS

The cement kiln is the major direct-fired energy consumer in the cement industry. The Bureau of Mines reports domestic plants produced 69.8 x 10^6 tons of clinker in 1980.[1]

Plant capacity data were obtained from the Portland Cement Association's (1980) publication.[1] The Bureau of Mines provides data on both the percentage of capacity utilized by cement plants in various regions of the United States and unit energy consumption.[2] Estimates indicate the cement kiln consumes approximately 5.9 x 10^6 Btu/ton. Most plants burn coal as their primary fuel and oil as an alternative.[1]

Table 3-4 presents the NO_x emission factor applied to cement kilns. Estimates indicate the cement kiln emits NO_x at a rate of approximately 2.6 lb/ton.[3]

REFERENCES

1. Portland Cement Association. U.S. and Canadian Portland Cement Industry. Plant Information Summary. Skokie, Illinois.

2. U.S. Department of the Interior. Minerals Yearbook. Volume I. Metals and Minerals. Bureau of Mines. 1980.

3. U.S. Environmental Protection Agency. Compilation of the Air Pollutant Emission Factors. 3rd Edition (including Supplements 1 through 13, Final). Research Triangle Park, North Carolina. 1977.

INDUSTRY: GLASS

PLANT/FACILITY: CONTAINER GLASS PLANTS

Approximately 109 container glass plants produced 12.94 x 10^6 tons of glass in 1980.[1,2] The major direct-fired processes in this industry include melting, conditioning, forming, and post-forming.

Plant capacity and production are considered proprietary; therefore, these data are extremely difficult to obtain. In lieu of plant-specific data, U.S. production was apportioned to each plant based on its share of the U.S. market.

The Glass Packaging Institute (GPI) reported 1980 container glass production as 12.9 x 10^6 tons.[2] Apportioning of total U.S. production was accomplished by using the Economic Information Systems, Inc., 1982 Shipments Report.[1] This report estimates each company's shipments and their share (based on shipments) of the U.S. market. Assuming each company's market share is directly equated with their production, total production can be apportioned to individual plants.

Industry experts indicate the total U.S. 1980 fuel consumption for container glass plants to be 127.4 x 10^{12} Btu/year.[2] Direct-fired sources account for 96.4 x 10^{12} Btu/year or 7.4 x 10^6 Btu/ton.[2,3] The melting furnace represents the largest energy-consuming direct-fired process.

A breakdown of total plant energy consumption indicates that natural gas accounts for about 83 percent, electricity 12.5 percent, and other fuels 4.5 percent.2 In the glass-melting furnace, natural gas represents 96 percent of all fossil fuel consumption.[2] Based on these data, natural gas is assumed to be the only fuel used in direct-fired processes.

Table 3-4 presents the NO_x emission factor used for this industry. The specific emission factor applied to the container glass-melting furnace is 6.2 lb/ton.[4] Since the glass-melting furnace accounts for approximately 90 percent of the direct-fired energy consumption, the above emission factor has been applied to all the direct-fired process equipment in this industry.

REFERENCES

1. Economic Information Systems, Inc. Shipments Report. SIC 3221 - Container Glass. New York. 1982.

2. Personal communication from R. Laughman, Anchor Hocking, to D. Orf, PEDCo Environmental, Inc., March 1982.

3. Battelle Columbus Laboratories. Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing. Prepared for Bureau of Mines. June 1975.

4. U.S. Environmental Protection Agency. Compilation of the Air Pollutant Emission Factors. 3rd Edition (including Supplements 1 through 13, Final). Research Triangle Park, North Carolina. AP-42, 1977.

INDUSTRY: GLASS

PLANT/FACILITY: FLAT GLASS PLANTS

The major products manufactured by this industry include float, sheet, rolled, and plate glass. Direct-fired energy is consumed during melting, forming, and post-forming. The melting furnace accounts for approximately 90 percent of the total direct-fired energy.[1]

This industry consists of 28 operating plants. In 1977, these plants produced approximately 2.62×10^6 tons per year.[1,2,3] Actual U.S. production is not available; it was estimated by using fuel consumption data (for purchased fuels), a direct-fired/indirect ratio (82:18), and the unit energy consumption factor (17.4×10^6 Btu/ton).[1,2] Plant capacity and production are considered proprietary; therefore, these data are extremely difficult to obtain. In lieu of plant-specific data, U.S. production was apportioned to each plant based on its share of the U.S. market.[3] Four plants account for slightly more than 38 percent of the total U.S. production.[3]

Detailed energy data are considered highly proprietary. Estimates based on the limited data available, however, indicate that this industry used 21×10^6 Btu/ton for all processes.[1] The melting, forming, and post-forming processing segments of the flat glass industry account for about 82 percent of this total.

Therefore, the unit energy consumption for direct-fired processes is roughly 17.4 x 10^6 Btu/ton.[1] Natural gas is consumed almost exclusively in the melting furnace.

Table 3-4 presents the NO_x emission factor used for this industry. The NO_x emission factor specifically applicable to the melting furnace is 8.0 lb/ton.[4] This emission factor was assumed to be representative of forming and post-forming NO_x emissions. Specific emission factors for these two processes were not available.

REFERENCES

1. Battelle Columbus Laboratories. Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing. PB 245759, June 1975.

2. U.S. Department of Commerce. 1977 Census of Manufacturers. Fuels and Electric Energy Consumed. Part 1. Industry Groups and Industries. September 1980.

3. Economic Information Systems, Inc. Shipments Report. SIC 3211 - Flat Glass. New York. 1982.

4. U.S. Environmental Protection Agency. Compilation of the Air Pollutant Emission Factors. 3rd Edition (including Supplements 1 through 13, Final). Research Triangle Park, North Carolina. AP-42, 1977.

INDUSTRY: GLASS

PLANT/FACILITY: PRESSED AND BLOWN GLASS PLANTS

The major products manufactured by pressed and blown glass plants include textile glass fibers; lighting, electronic, and technical ware; and machine-made and handmade tableware, kitchenware, and artware. Direct-fired energy is consumed during melting, forming, and post-forming. The melting furnace accounts for approximately 66 percent of the total direct-fired energy.[1]

This industry is composed of 83 operating plants. In 1977 these plants produced approximately 1.81 x 10^6 tons.[1,2,3,4] Actual 1977 U.S. production is not available; it was estimated by using fuel consumption data (for purchased fuels), a direct-fired ratio (90:10), and the unit energy consumption factor (33.3 x 10^6 Btu/ton). Plant capacity and production data are not available. In lieu of plant-specific data, U.S. production was apportioned to each plant based on its share of the market.[3] Three plants produced over 33 percent of the total U.S. production.[3]

A detailed energy analysis of this industry is difficult because of the diversity of endproducts, units for reporting production, manufacturing techniques, and raw materials. Unit energy consumption for all direct-fired processes is approximately 33.3 x 10^6 Btu/ton.[4] Natural gas is the preferred fuel for the melting furnace.

The specific NO_x emission factor applied to this industry was 8.5 lb/ton.[5] This emission factor applies to the melting furnace; however, because emission factors were not available for the forming and post-forming processes, it has been assumed that the melting furnace emission factor is applicable to all direct-fired combustion processes.

REFERENCES

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2. U.S. Department of Commerce. 1977 Census of Manufacturers. Fuels and Electric Energy Consumed. Part I. Industry Groups and Industries. September 1980.

3. Economic Information Systems, Inc. Shipments Report. SIC 3229 - Pressed and Blown Glass. New York. 1982.

4. Battelle Columbus Laboratories. Industrial Energy Study of the Glass Industry. Prepared for the Federal Energy Administration. December 1974.

5. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. 3rd Edition (including Supplements 1 through 13, Final). Research Triangle Park, North Carolina. AP-42, 1977.

INDUSTRY: MINERAL WOOL

PLANT/FACILITY: MINERAL WOOL

For purposes of this study, mineral wool is defined to include only that made primarily from natural rock or metallurgical slag. The rock and/or slag are melted in a cupola. The molten minerals are then fiberized on a spinning rotor (by use of a high velocity stream of air or steam) to assist in fiber attenuation and finally collected on a wire-mesh conveyor. Most mineral wool is cut into batts, and it is usually covered with a vapor barrier of treated paper or foil.

There are approximately 26 plants operating in the United States,[1] four of which are within the study area. These include two Bethlehem Steel Corporation facilities (in Bethlehem, Pennsylvania), a U.S. Mineral Products plant (Standhope, New Jersey), and a Celotex plant (Pittston, Pennsylvania). Production data for individual facilities were not readily available. All data determined were based on a typical/average plant throughput and attributed to each of the individual target area facilities. It is anticipated that facility-specific estimated production, or market share, is obtainable through the EIS Mineral Wool Shipment Report.[2] Further refinement of these data would require acquisition of this report.

The principal processing NO_x emissions occur from the direct firing of the cupola furnaces with coke. Both production and emission data were available on the basis of per ton of charge to the furnace.[1] An annual cupola charge figure for the entire industry was identified as 1.35×10^6 tons.[1] A 60 percent input volume reduction was specified as output from the furnace to final product.[1] Therefore, total mineral wool production was determined as 0.81×10^6 tons/year. When considering the 26 plants as constituting the industry, the average plant contribution then is approximately 31,150 tons. Nitrogen oxide emissions from the cupola have been identified as occurring at 1.6 lb/ton of material charged.[1] Conversion of this factor to pound per ton of product would be as follows:

$$\frac{(1.35 \times 10^6 \text{ tons})(1.6 \text{ lb/ton})}{(0.81 \times 10^6 \text{ tons})} = 2.7 \text{ lb/ton product}$$

Cupola emissions from a typical plant would be approximately 42 tons/yr.

Energy consumption data were calculated from the 1979 purchased coke (and breeze) used[3] by the industry and an average heat estimate per ton of coke,[4] as follows:

$$(101{,}400 \text{ tons})(25.993 \times 10^6 \text{ Btu/ton}) = 2.636 \times 10^{12} \text{ Btu}$$

This yielded a consumption per ton of product of 3.25×10^6 Btu/ton and a typical-facility annual consumption of 0.101×10^{12} Btu.

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INDUSTRY: IRON AND STEEL

PLANT/FACILITY: INTEGRATED PLANTS

The direct-fired processes considered in the integrated iron and steel industry include:

- Sinter plant
- Coke plant
- Blast furnace stoves
- Basic oxygen furnace (BOF)
- Electric arc furnace
- Soaking pits
- Continuous casting
- Reheating furnaces

These processes account for the majority of direct-fired energy consumed at an integrated plant. Some direct-fired energy also can be attributed to the vacuum degasser, heat treating, and annealing furnaces. These three processes were not considered, however, because of their relatively small contribution to the plant's overall direct-fired energy consumption (less than 100 x 10^9 Btu/yr each) and the difficulty involved in identifying their associated production capacity.

Steelmaking practices in the integrated iron and steel industry vary considerably from plant to plant. Several site-specific factors need to be taken into consideration when estimating energy consumption and associated emissions. For instance, integrated steel plants can produce raw steel by utilizing one or more of the following furnaces:

- Basic oxygen (0.2×10^6 Btu/ton)
- Open hearth (3.3×10^6 Btu/ton)
- Electric arc (0.1×10^6 Btu/ton)

Energy consumption varies according to the quantity of raw steel produced and the type(s) of furnace(s) used at a particular plant. Raw steel is either poured into ingots or continuously cast; a plant can have either or both processes. Direct-fired energy is consumed during continuous casting. Reheat furnaces are associated with many mills, but they are not used in in-line mills. All of these factors must be taken into consideration when estimating direct-fired energy consumption.

The developed methodology has built in this necessary flexibility. Table B-2 illustrates this methodology by using the Bethlehem Steel Corporation plant in Bethlehem, Pennsylvania, as an example. At this plant, fossil fuels are consumed as feedstock in the sinter plant, blast furnace, and electric furnace. The consumption of fuels as feedstock is not considered or incorporated into the direct-fired energy consumption estimates. Unit energy consumptions and capacities of the direct-fired processes came from in-house files and published information.[1-9] Because little information is available on annual plant production, percent utilization of capacity was used to estimate production. A national average percent utilization was estimated from total 1977 raw steel production and capacity in the United States.[4]

A plant-specific breakdown of the fuels consumed in direct-fired processes is not possible. The types of fuels consumed vary from day to day and from plant to plant. Generally, by-

TABLE B-2. TOTAL ENERGY CONSUMPTION OF DIRECT-FIRED PROCESSES OF THE BETHLEHEM STEEL CORPORATION'S, BETHLEHEM PLANT

Process	Unit energy consumption[a,b,c,d]	Annual capacity	Percent utilization[e]	Annual energy consumption, 10^9 Btu/yr
Sinter plant	0.29×10^6 Btu/ton sinter	2.4×10^6 ton sinter/year[f]	0.6744	470
Coke plant	3.10×10^6 Btu/ton coke	2.0×10^6 ton coke/year[g]	0.6744	4182
Blast furnace stoves	1.90×10^6 Btu/ton pig iron	3.87×10^6 ton pig iron/year[g]	0.6744	4959
BOF	0.20×10^6 Btu/ton raw steel	2.70×10^6 ton raw steel/year[h]	0.6744	364
Electric furnace	0.10×10^6 Btu/ton raw steel	0.33×10^6 ton raw steel/year[g]	0.6744	22
Open hearth	3.30×10^6 Btu/ton raw steel	0.00×10^6 ton raw steel/year[g]	0.6744	0
Soaking pits	1.40×10^6 Btu/ton ingot steel	2.20×10^6 ton ingot steel/year[g,i]	0.6744	2078
Continuous casting-slab	0.10×10^6 Btu/ton steel	0.90×10^6 ton steel/year[g]	0.6744	61
Reheat furnace	2.00×10^6 Btu/ton steel	1.12×10^6 ton steel/year[i]	0.6744	1510

[a] Vaughan, W. J. Residuals Management Model of Iron and Steel Industry: A Linear Programming Approach. Ph.D. Thesis. Georgetown University. 1975.

[b] Battelle Columbus Laboratories. Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing. Prepared for the Bureau of Mines, September 1975.

[c] American Iron and Steel Institute. 1980 Annual Statistical Report. Washington, D.C., 1981.

[d] Koinis, F. J., et al. "Improved Thermal Efficiency in Reheat Furnaces Through Heat Transfer Analysis and Correlation," Iron and Steel Engineer. (59)(2):43-46. February, 1982.

[e] Pietrucha, W. E., et al. Steel Industry in Brief: Databook, U.S.A. 1977. Institute for Iron and Steel Studies, Green Brook, New Jersey. 1977.

[f] PEDCo Environmental, Inc. Revised Technical Approach for a Coke Production Cost Model. EPA 68-02-3554, January, 1981.

[g] PEDCo Environmental, Inc. Development of Air Pollution Control Cost. Functions for the Integrated Iron and Steel Industry. EPA 68-01-4600, 1979.

[h] 33 Metal Producing. World Steel Industry Data Handbook. Volume 1. The United States. Published by McGraw-Hill Publications Company, New York. 1978.

[i] American Iron and Steel Institute. Directory of Iron and Steel Works of the U.S. and Canada. Washington, D.C., 1980.

product gases (i.e., coke oven gas, blast furnace gas) are fired with natural gas or fuel oil; however, the percentages vary depending on the availability of the byproduct gases. Natural gas is used almost exclusively in the basic oxygen furnace and during continuous casting. A relative percentage breakdown of fuels for the remaining steelmaking furnaces and other processes is shown below:[3]

	Steelmaking	Blast furnace area	Other equipment
Fuel oil	25.96	Neg.	5.37
Tar and pitch	12.27	Neg.	Neg.
Natural gas	55.15	15.17	41.42
Coke oven gas	5.00	5.24	22.78
Blast furnace gas	1.62	79.57	30.36

Table 3-4 presents the NO_x emission factors, which were available from various published sources. Emission factors (in lb/ton) were as follows: sinter plant (1.8), coke oven (1.89), blast furnace stoves (0.34), electric furnace (0.01), open hearth (4.5), reheating furnace (1.1), and soaking pits (0.8).[10,11] Specific factors were not available for the BOF or continuous casting. Since both of these processes consume natural gas, the graph shown in Figure 3-4 was used to estimate NO_x emissions.[12]

It should be noted that the NO_x emission estimates also include merchant coke plants (i.e., those associated with chemical companies, gas utilities, or plants producing coke and coal chemicals sold on the open market) and furnace coke plants not on the same site as the integrated steel mill. A breakdown of the energy use and NO_x emissions from these plants is included with the summary of integrated steel mill emissions presented in Appendix C.

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INDUSTRY: IRON AND STEEL

PLANT/FACILITY: MINI AND MIDI PLANTS

Mini and midi plants can be differentiated from integrated steel plants by their size and their raw material input. These plants start with scrap rather than ore. The direct- fired processes considered in this industry include soaking pits and reheating furnaces.

Basically, the methodology developed for the integrated iron and steel industry was applied to mini and midi plants. Capacity data for the soaking pits and reheating furnaces were obtained from the American Iron and Steel Institute,[1,2] and a capacity factor of 67.44 percent was applied to estimate production.

Unit energy consumptions for soaking pits and reheating furnaces are 1.4×10^6 Btu/ton and 2.0×10^6 Btu/ton, respectively.[3,4,5] The overall fuel breakdown for natural gas, and fuel oil is 86.3 percent and 13.7 percent, respectively.[1]

Table 3-4 presents the NO_x emission factors applied to these direct-fired processes. The NO_x emission factors applied to the soaking pit and reheating furnace are 0.8 and 1.1 lb/ton, respectively.[6]

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INDUSTRY: IRON AND STEEL

PLANT/FACILITY: IRON FOUNDRIES

Iron foundries produce the following castings: metal molds, pipes, and a variety of specialized forms and parts. Although many ferrous foundries cast more than one metal, iron foundries can generally be categorized by their production of gray iron, ductile iron, or malleable iron castings. In 1980, approximately 1396 U.S. iron foundries produced 12.3×10^6 tons.[1]

Estimates indicated that 44 percent of all iron foundries were small operations having fewer than 50 employees.[1] The number of small foundries has been decreasing over the past decade, and this trend is expected to continue. Because preliminary energy estimates indicated these small foundries would not meet the established annual direct-fired energy consumption criterion (100×10^9 Btu/plant), the study population includes only those plants with 50 or more employees, which reduced the number of plants in the 150-county study area to 64.[2]

The cupola used during metal melting is the major direct-fired equipment found in this industry. Because plant-specific production is not readily available, it was estimated by using available data.

Davis et al.[3] developed various foundry size classifications based on foundry employment, which were adopted for this analysis. The two size categories were large ($\geq$250 employees) and medium (50-249 employees). The operating hours for the two employment ranges were then estimated (using NEDS data[5]) by taking the median value of the operating hours in the range of operators hours for the large- and medium-size foundry categories. By use of Penton capacity data (summarized in Reference 5), average hourly production rates were developed for the two size categories. Table B-3 presents these data for medium and large foundries. This methodology could be improved by using actual 1974 production data from the Penton Directory, but these data could not be obtained in time for this report.

Direct-fired energy requirements for the cupola are estimated at 3.38×10^6 Btu/ton.[6] Coke is fired exclusively. Table 3-4 presents the NO_x emission factor used for this industry. Estimates indicate the cupola emits 0.11 lb/ton.[7]

TABLE B-3. PRODUCTION RANGES FOR MEDIUM AND LARGE IRON FOUNDRIES

	Employment size,[3] employees	Average production,[3] tons/yr	Median annual operation,[4] hours
Large	>250	51.25	5150
Medium	50-249	12.50	2500

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INDUSTRY: SECONDARY NONFERROUS SMELTING

PLANT/FACILITY: ALUMINUM SMELTING

The secondary aluminum industry processes aluminum-bearing scrap to produce the following products:

- Alloy ingots
- Billets
- Hot metal
- Shot
- Notched bar
- Hardners
- Fines

Alloy ingots are the most important, followed by billets. The major pieces of direct-fired equipment in this industry are sweating furnaces and reverberatory furnaces.[1,2]

The Bureau of Mines estimated 1980 production for this industry as 793,000 tons/yr.[3] Approximately 89 secondary aluminum smelters were operating.[4,5] Because plant-specific production data are not readily available, an average production rate was estimated at 8900 tons per year (by dividing the number of operating plants into 1980 production). This methodology could be further refined by using Economic Information Systems, Inc., Shipments Report for the Secondary Nonferrous Industry,[6] which provides data on each plant's share of the market.

Unit energy consumption generally runs 1.31×10^6 Btu/ton for the sweating furnace and 52.81×10^6 Btu/ton for the reverberatory furnace.[1] Both furnaces fire natural gas or oil.

Although the exact split between these two fuels is not known, it can be approximated by using Census data.[7] Based on these calculations, the secondary aluminum smelting industry consumed 75 percent natural gas and 25 percent oil in their direct-fired equipment.[1,2,7]

Table 3-4 presents the NO_x emission factors applied to the sweating and reverberatory furnaces. The specific NO_x emission factors applied to the sweating and reverberatory furnaces were 0.15 lb/10^6 Btu and 0.12 lb/ton, respectively.[8]

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INDUSTRY: SECONDARY NONFERROUS METALS

PLANT/FACILITY: COPPER SMELTING AND REFINING

Secondary copper can be produced at primary copper smelters, secondary copper smelters, brass and bronze mills (as an alloy), and secondary copper foundries. Products of the secondary copper industry include copper shot, copper powder, fire-refined copper, electrolytically refined copper, oxygen-free high-conductivity copper, and white metal alloys.[1] Only secondary copper smelters are considered in this methodology. Secondary copper produced at primary smelters and refineries are included in a separate methodology (no primary copper plants are located within the study area). Brass and bronze mills and copper foundries were eliminated from consideration during the preliminary industry review.

In general, direct-fired energy at a secondary copper smelter can be consumed during drying, insulation burning, sweating, blast furnace (cupola)/reverberatory smelting, converter smelting, and fire-refining. Of these direct-fired processes, only sweating, blast furnace/reverberatory smelting, and fire-refining (reverberatory furnace) are considered. These processes represent the typical plant configuration and meet the established energy consumption criteria.[1]

The Bureau of Mines estimates that domestic secondary copper smelters recovered 595,000 tons of refined copper, copper alloys and other copper products from copper-based scrap in 1980.[2] Refined copper from copper-based scrap accounts for approximately 220,000 tons. The Bureau of Mines also estimates that there are 43 secondary copper smelters.[4] Nine of these secondary smelters produce refined copper.[3] This industry is characterized by a few relatively large producers and numerous small facilities.[5] Only 19 smelters are located in the study area; one produces refined copper.[6]

Production data for this industry are not readily available. As shown in Table B-4, capacity data have been previously estimated for seven of the nine U.S. smelters producing refined copper.[4] A 1980 capacity utilization factor of 34 percent has been estimated for these plants.[2,4] An average production rate (11,000 ton/yr) for the remaining plants was estimated by subtracting the 220,000 tons of refined copper from the 595,000 tons of total production and dividing by 34 (the number of plants involved only in smelting). This methodology could be refined by using Economic Information Systems, Inc., Shipments Report for the Secondary Nonferrous Industry, which provides each plant's share of the market.[7]

Unit energy consumption for the sweating furnace, blast furnace, smelting reverberatory furnace, and fire-refining reverberatory furnace are 0.43×10^6, 2.10×10^6, 5.92×10^6, and 0.67×10^6 Btu/ton, respectively. Coke is used in both the blast and

TABLE B-4. SECONDARY COPPER SMELTING AND REFINING PLANTS[3]

Company[a]	Location	Employees	Estimated capacity, tons/month
Southwire	Georgia	200	3,000
Cerro Copper Products	Illinois	900	4,400
Chemeto	Illinois	200	3,000
U.S. Metals Refining	New Jersey	1,600	15,920
Franklin Smelting and Refining	Pennsylvania	150	1,500
Reading Metals Refining	Pennsylvania	100	7,000
Nassau Recycling	South Carolina	1,200	10,420

[a] Includes only those secondary companies that smelt and refine scrap.

reverberatory smelting furnaces.[1,8] Because data were not available on the types of fuels consumed by the sweating and fire-refining furnaces, estimates were made based on Census data.[9] These estimates indicate an overall ratio of fuel use for the direct-fired processes as 89 percent coke, 7 percent natural gas, 2 percent oil, and 2 percent coal.

Table 3-4 presents the NO_x emission factors used for each furnace. Emission factors applied to the blast furnace (cupola) and two reverberatory furnaces (smelting and fire refining) were 0.56 lb/ton and 0.96 lb/10^6 Btu, respectively.[10]

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INDUSTRY: SECONDARY NONFERROUS METALS

PLANT/FACILITY: LEAD SMELTERS

The secondary lead smelting industry processes lead-bearing scrap to produce any of the following products: soft lead ingots, semisoft lead ingots, hard lead ingots, other lead alloy ingots, battery lead oxide, and lead pigments.

Soft lead is a high-purity product. Semisoft lead contains some impurities and is usually produced in a reverberatory furnace. Hard or antimonial lead is considered an alloy and is generally produced in a blast furnace. Secondary lead can be produced at primary or secondary smelters and refineries. This methodology considers only the production at secondary lead plants.

Processing equipment varies from plant to plant depending on the desired end product. The major direct- fired process equipment in this industry includes blast furnaces, reverberatory furnaces, and pot or kettle furnaces. Based on available energy consumption data and a typical plant processing configuration, only the blast and reverberatory furnaces are considered in this study.[1,2]

The Bureau of Mines estimates that approximately 58 secondary plants recovered 728,000 tons of metallic lead and lead alloys in 1980.[3,4] Production capacities are available for most plants (42 out of 58 plants).[4] Assuming that those secondary lead plants with available production capacity data represent approximately

90 percent of the total production,[5] the percent utilization of capacity can be calculated. This calculation (using 90% of total production and available production capacity data) indicates secondary lead plants utilized 67 percent of their capacity in 1980. An average plant production rate of 4600 tons per year was assigned to those plants on which no capacity data were available. The average production rate was determined by taking 10 percent of total production and dividing by the number of plants without production capacities (16). This methodology could be refined by using Economic Information Systems, Inc., Shipment Reports, which provide each plant's share of the market.[6]

Soft/semisoft lead and hard lead each account for about 50 percent of total production.3 Assuming all soft/semisoft lead is produced in a reverberatory furnace, hard lead in a blast furnace, and a 50/50 production split at each plant,[1] unit energy consumption was determined to be approximately 4.76×10^6 Btu/ton for the reverberatory furnace and 1.64×10^6 Btu/ton for the blast furnace.[1] Coke is the primary fuel in the blast furnace, while oil or gas is generally fired in the reverberatory furnace.[2] The split between these fuels is approximately 26 percent coke, 56 percent natural gas, and 18 percent oil.[1,2,7]

Table 3-4 presents the NO_x emission factors for the secondary lead blast and reverberatory furnaces. These NO_x emission factors are 0.58 lb/ton for the blast furnace and 0.38 lb/10^6 Btu for the reverberatory furnace.[8]

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INDUSTRY: PRIMARY ALUMINUM FABRICATION

PLANT/FACILITY: ALUMINUM SHEET, PLATE AND FOIL

The United States has approximately 68 aluminum sheet, plate, and foil fabrication plants, 10 of which are located within the study area.[1,2] Total U.S. production in 1977 has been estimated as 3.5×10^6 tons;[3] aluminum sheet products account for 86 percent of total production, foil for 10 percent, and plate for 2 percent.[3] During aluminum fabrication, direct- fired energy is consumed in the reverberatory melting furnace and the heat treating furnace.

The reverberatory furnace is a box-like direct-fired furnace with a holding capacity of 20,000 to 100,000 pounds.[4] Fabricating plants generally operate these furnaces near 100 percent capacity. Process rates of modern reverberatory furnaces can peak at 10,000 pounds per hour.[4]

Heat treating furnaces employ two firing methods. In some furnaces the burners are encased in radiant tubes, which prevent combustion products from contacting the furnace charge. Radiant tube furnaces contain 25 to 50 burners with typical heat release rates of 200 to 750×10^9 Btu/hr.[4] (The radiant tube furnace is used when high product quality is necessary.) In the second firing configuration, the burners are located in the side walls and discharge directly into the fire box, allowing products of combustion to contact the furnace charge.

Plant-specific production data are considered proprietary and are difficult to obtain. In lieu of plant-specific data, an average plant production rate was estimated by dividing total U.S. production by the number of plants. This methodology could be refined by acquiring the EIS Shipments Report, which provides each plant's share of the market.5

The reverberatory melting furnace, which consumes 11.0 x 10^6 Btu/ton of product,[4,6] is fired with a combination of natural gas and oil. The split between these two fuels is generally 90 percent for natural gas and 10 percent for fuel oil. The heat treating furnace, which consumes on the average 13.6 x 10^6 Btu/ton, is fired exclusively with natural gas.[4,6]

Table 3-4 presents the method used to estimate NO_x emissions from these furnaces. Specific emission factors were not available for these furnaces. Emissions were estimated by using the graphs shown in Figures 3-3 and 3-4.[7]

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4. Energy and Environmental Analysis, Inc. The Technical Feasibility of Coal Use in Industrial Process Heat Applications. DOE EJ-78-C-01-2832, June 1978.

5. Economic Information Systems, Inc. Shipments Report, SIC 3353 - Aluminum Sheet, Plate, and Foil. New York. 1982.

6. PEDCo Environmental, Inc. Review of Energy Consumption in Major Industrial Direct-Fired Processes. DOE 31-109-38-6667, April 1982.

7. Mills, J. L., et al. Emissions of Oxides of Nitrogen from Stationary Sources in Los Angeles County. Report No. 4. Prepared for Los Angeles County APCD, Los Angeles, California. 1961.

PART 2

INDUSTRIAL BOILERS

INDUSTRIAL BOILER METHODOLOGY

The purpose of this segment of the study was to estimate the emissions resulting from the operation of large industrial boilers (i.e., those with capacities equal to or greater than 250×10^6 Btu/h). Before this could be accomplished, it was first necessary to identify the large boiler installations in the 150-county study area and to acquire data on fuel consumption.

Several principal sources were evaluated for pertinent data:

1) National Emission Data System (NEDS) printouts of industrial boilers for the states in the study area; these were acquired for this study from EPA's Office of Air Quality Planning and Analysis.

2) Major Fuel Burning Installation (MFBI) printouts for these states; these were acquired from Argonne National Laboratory.

3) EPA's Industrial Boiler FGD Survey, a series of quarterly reports describing boiler installations with flue gas desulfurization systems.

4) Other industry-specific reports that contain information on boiler installations (e.g., PEDCo in-house data file).

5) Trip reports and other documentation relating to boiler inspections made by PEDCo engineers under contract to the Department of Energy.

6) Industry journals.

The NEDS printouts proved to be the most comprehensive source of information because they presented boiler capacity, fuel consumption, and estimated NO_x emissions for each source.

The NEDS data were therefore chosen as the primary source, with information from other sources used as needed to resolve uncertainties or to characterize sources not found in NEDS.

Combustors with capacities greater than 250 x 10^6 Btu/h in the study area were first identified from the NEDS printouts through examination of the NEDS county codes and the unit design capacity. Boilers in this group were then identified through examination of the Source Classification Codes (SCC). Thirty-four installations were found to contain at least one boiler in this capacity range. The specific fuel type and quantity consumed and the NEDS-estimated NO_x emissions were recorded.

The MFBI printouts were then examined in an analagous manner. The units in the target counties were first identified, and then all that were not individual industrial boilers with capacities equal to or greater than 250 x 106 Btu/h were eliminated from consideration. After this screening, 24 installations remained. Because emissions estimates were not provided for the MFBI data, they were calculated based on reported fuel consumption by use of the following factors: coal - 14 lb NO_x/ton, residual oil - 55 lb NO_x/1000 gal, distillate oil - 20 lb/NO_x/1000 gal, natural gas - 140 lb NO_x/million cubic feet (see Table 3-5).

The NEDS and MFBI results were then compared. Eighteen of the 24 MFBI installations were also on the NEDS list. In cases where NEDS and MFBI differed regarding these 18 installations, the NEDS data were used for this study because NEDS represents the more recently collected information. The six MFBI installations not found in NEDS were also included in the study, which brought the total number of installations to 40.

The other data sources were then examined in an attempt to locate additional units that might belong in the study. Many of the units from NEDS or MFBI were also identified in these sources, but no new installations were found. The final population of boilers used for the study therefore consisted of 40 installations.

Finally, the total fuel consumption in Btu's was estimated by use of the following conversion factors: coal - 13,000 Btu/lb, residual oil - 150,000 Btu/gal, distillate oil - 139,000 Btu/lb, natural gas - 1,024 Btu/cubic foot, coke oven gas - 550 Btu/cubic foot, blast furnace gas - 94 Btu/cubic foot.

APPENDIX C

SUMMARY OF POPULATION AND LAND AREA FOR ALL 150 COUNTIES IN THE STUDY AREA

TABLE C-1. POPULATION AND LAND AREA FOR THE 150-COUNTY STUDY AREA

State/county	Population[a]	Land area, square miles[b]
Connecticut	3107576	4863
Fairfield	807143	626
Hartford	807766	739
Litchfield	156769	925
Middlesex	129017	372
New Haven	761337	604
New London	238409	667
Tolland	114823	416
Windham	92312	514
Massachusetts	5575383	7283
Berkshire	145110	941
Bristol	474641	554
Essex	633632	494
Franklin	64317	708
Hampden	443018	619
Hampshire	138813	529
Middlesex	1367034	825
Norfolk	606587	394
Plymouth	405437	654
Suffolk	650142	56
Worchester	646352	1509
New Hampshire	920610	9028
Belknap	42884	400
Carrol	27931	938
Chesire	62116	715
Coos	35147	1820
Grafton	65806	1732
Hillsborough	276608	887
Merrimack	98302	930
Rockingham	190345	691
Strafford	85408	376
Sullivan	36063	539
New Jersey	6218664	5270
Bergen	845385	234
Burlington	362542	819
Essex	850451	130
Hudson	556972	47
Hunterdon	87361	423
Mercer	307863	228
Middlesex	595893	312
Monmouth	503173	476
Morris	407630	468
Ocean	346038	642
Passic	447585	192
Somerset	203129	307
Sussex	116119	527
Union	504094	103
Warren	84429	362

(continued)

TABLE C -1 (continued)

State/county	Population[a]	Land area, square miles[b]
New York	17097565	44908
Albany	285909	526
Allegany	51742	1047
Bronx	1169115	41
Broome	213648	714
Cayuga	79894	698
Chemung	97656	415
Chenango	49344	903
Clinton	80750	1059
Columbia	59487	645
Cortland	48820	502
Deleware	46931	1443
Dutchess	245055	813
Erie	1015472	1058
Essex	36176	1823
Franklin	44929	1674
Fulton	55153	498
Genesee	59400	501
Greene	40861	653
Hamilton	5034	1735
Herkimer	66714	1435
Jefferson	88151	1294
Kings	2230936	70
Lewis	25035	1291
Livingston	57006	638
Madison	65150	661
Monroe	702238	675
Montgomery	53439	408
Nassau	1321582	289
New York	1427533	23
Oneida	253466	1223
Onondaga	463324	794
Ontario	88909	651
Orange	259603	833
Orleans	38496	396
Oswego	113901	964
Otsego	59075	1013
Putnam	77193	231
Queens	1891325	108
Rensselaer	151966	665
Richmond	352121	58
Rockland	259530	176
St. Lawrence	114254	2768
Saratoga	153759	818
Schenectady	149946	207
Schoharie	29710	624
Schuyler	17686	330

(continued)

TABLE C-1 (continued)

State/county	Population[a]	Land area, square miles[b]
Seneca	33733	330
Steuben	99135	1410
Suffolk	1284231	929
Sullivan	65155	988
Tioga	49812	524
Tompkins	87085	482
Ulster	158158	1141
Warren	54854	887
Washington	54795	836
Wayne	85230	606
Westchester	866599	443
Wyoming	39895	598
Yates	21459	343
Pennsylvania	3892206	18036
Berks	312509	862
Bradford	62919	1148
Bucks	479211	614
Carbon	53285	404
Centre	112760	1115
Clinton	38971	899
Columbia	61967	484
Dauphin	232317	518
Lackawanna	227908	454
Lebanon	109829	363
Lehigh	273582	348
Luzerne	343079	886
Lycoming	118416	1216
Monroe	69409	611
Montgomery	643621	496
Montour	16675	130
Northampton	225418	376
Northcumberland	100381	453
Pike	18271	542
Potter	17726	1092
Schuylkill	160630	784
Synder	33584	327
Sullivan	6349	478
Susquehanna	37876	833
Tioga	40973	1146
Union	32870	318
Wayne	35237	741
Wyoming	26433	398
Rhode Island	947154	1050
Bristol	46942	25
Kent	154163	173
Newport	81383	115
Providence	571349	416
Washington	93317	321

(continued)

TABLE C-1 (continued)

State/county	Population[a]	Land area, square miles[b]
Vermont	511456	9266
Addison	29406	784
Bennington	33345	672
Caledonia	25808	612
Chittenden	115534	533
Essex	6313	663
Franklin	34788	660
Grand Isle	4613	83
Lamoille	16767	474
Orange	22739	690
Orleans	23440	715
Rutland	58347	927
Washington	52393	707
Windham	36933	784
Windsor	51030	962

[a] U.S. Department of Commerce. 1980 Census of Population and Housing. Bureau of the Census. 1981.

[b] PEDCo Environmental, Inc. Program to Prevent the Significant Deterioration of Carbon Monoxide, Ozone, Hydrocarbons, Nitrogen Dioxide, and Lead. March 1980.

APPENDIX D

DETAILED BREAKDOWN OF PRODUCTION, FUEL CONSUMPTION AND NO_x EMISSIONS FOR POINT AND AREA SOURCES IN THE 150-COUNTY STUDY AREA

PART 1 - MAJOR DIRECT-FIRED SOURCES

PART 2 - INDUSTRIAL BOILERS

PART 3 - TRANSPORTATION, RESIDENTIAL, AND COMMERCIAL SECTORS

NOTE: Please see Appendix B for information on the methodologies and references utilized in generating the results presented here for direct-fired sources and industrial boilers. The methodologies (and references) utilized for the transportation, residential, and commercial sector results are presented in Section 3.3 of the main text.

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PART 1

MAJOR DIRECT-FIRED POINT SOURCES

INDUSTRY: PETROLEUM REFINING

FACILITY: PETROLEUM REFINING

EQUIPMENT: PROCESS HEATERS

FUEL: REFINERY GAS(69%), NATURAL GAS(25%), CO GAS(1%), AND RESIDUAL OIL(5%)

PLANT NAME	COUNTY	LOCATION	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
ATP PETROLEUM INC	ROCKINGHAM	NEWINGTON,NH	479	37
CHEVRON USA, INC	MIDDLESEX	PERTH AMBOY,NJ	17188	1310
EXXON OIL USA	UNION	LINDEN,NJ	36795	2805
CIBRO PETROLEUM PRDCTS INC	ALBANY	ALBANY,NY	1237	94
ASHLAND OIL INC	ERIE	BUFFALO,NY	7335	559
MOBIL OIL CORP	ERIE	BUFFALO,NY	4491	342
		TOTAL	67525	5147

ENERGY FACTOR, 10E3BTU/BBL		103	125	300	113	314	333	57	85	336	600

CAPACITY
BBL/SD

PLANT NAME	LOCATION	ATMOS DIST	VACUUM DIST	THERMAL OPER	CAT CRACKING	CAT REFORM	HYDRO CRACKING	HYDRO REFINING	HYDRO TREATING	ALKYL-ATION	AROMATIC MFG
ATP PETROLEUM INC	NEWINGTON,NH	14100	0	0	0	0	0	0	0	0	0
CHEVRON USA, INC	PERTH AMBOY,NJ	180000	96000	0	33000	39000	0	80000	0	3000	0
EXXON OIL USA	LINDEN,NJ	285000	155000	0	120000	42000	0	50000	159000	8500	28000
CIBRO PETROLEUM PRDCTS INC	ALBANY,NY	36405	0	0	0	0	0	0	0	0	0
ASHLAND OIL INC	BUFFALO,NY	64000	28000	0	22000	11000	0	15200	11000	2000	6200
MOBIL OIL CORP	BUFFALO,NY	44000	18000	0	19000	11500	0	0	12500	0	0
	TOTAL	623505	297000	0	194000	103500	0	145200	182500	13500	34200

ENERGY
10E9BTU/YR

PLANT NAME	LOCATION	ATMOS DIST	VACUUM DIST	THERMAL OPER	CAT CRACKING	CAT REFORM	HYDRO CRACKING	HYDRO REFINING	HYDRO TREATING	ALKYL-ATION	AROMATIC MFG
ATP PETROLEUM INC	NEWINGTON,NH	479	0	0	0	0	0	0	0	0	0
CHEVRON USA, INC	PERTH AMBOY,NJ	6118	3960	0	1231	4041	0	1505	0	333	0
EXXON OIL USA	LINDEN,NJ	9687	6394	0	4475	4352	0	941	4460	942	5544
CIBRO PETROLEUM PRDCTS INC	ALBANY,NY	1237	0	0	0	0	0	0	0	0	0
ASHLAND OIL INC	BUFFALO,NY	2175	1155	0	820	1140	0	286	309	222	1228
MOBIL OIL CORP	BUFFALO,NY	1496	743	0	709	1192	0	0	351	0	0
	TOTAL	21192	12252	0	7235	10725	0	2732	5120	1497	6772

INDUSTRY: PETROCHEMICALS

FACILITY: PETROCHEMICAL PLANTS

EQUIPMENT: AMMONIA TUBULAR FURNACE

FUEL: NATURAL GAS

PLANT NAME	COUNTY	LOCATION	1981 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
FALMONT OIL CORP.	WYOMING	OLEAN,NY	82000	1320	238
NEW JERSEY ZINC	CARBON	PALMERTON,NJ	37000	596	107
		TOTAL	119000	1916	345

INDUSTRY: PHOSPHATE ROCK AND BASIC FERTILIZER

FACILITY: SODIUM PHOSPHATE

EQUIPMENT: DRYER AND KILNS

FUEL: NATURAL GAS(91%) AND OIL(9%)

PLANT NAME	COUNTY	LOCATION	1981 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	$ NOX EMISSIONS, TPY
MONSANTO INDSTRL CHMCLS CO	HUDSON	KEARNEY,NJ	73700	630	17
STAUFFER CHEMICAL CO	MONROE	MORRISVILLE,PA	16750	128	3
		TOTAL	90450	758	20

$ NOX EMISSIONS ATTRIBUTABLE TO DRYER AND KILNS ARE 55% AND 45%, RESPECTIVELY

INDUSTRY: PULP AND PAPER

FACILITY: PULP MILLS (KRAFT)

EQUIPMENT: LIME KILNS

FUEL:* COAL(6.1%), OIL(93.9%)

PLANT NAME	COUNTY	LOCATION	1980 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
BROWN COMPANY	COOS	BERLIN,NH	696000	5972	1044
INTERNATIONAL PAPER CO	ESSEX	TICONDEROGA,NY	46980	403	70
APPLETON PAPERS INC	BLAIR	ROARING SPRING,PA	20880	179	31
PENNTECH PAPERS INC	ELK	JOHNSONBURG,PA	34800	299	52
GLATFELTER CO, P.H.	YORK	SPRING GROVE,PA	52200	448	78
		TOTAL	850860	7301	1275

* REFLECTS FUEL CONSUMPTION IN THE STUDY AREA

ALL PLANTS USE FUEL OIL EXCEPT GLATFELTER CO PLANT

INDUSTRY: GYPSUM

FACILITY: GYPSUM PLANTS

EQUIPMENT: CALCINER

FUEL: NATURAL GAS

PLANT NAME	COUNTY	LOCATION	1980 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	* NOX EMISSIONS, TPY
U.S.GYPSUM CO	SUFFOLK	BOSTON,MA	134800	101	8
NATIONAL GYPSUM CO	ROCKINGHAM	PORTSMOUTH,NH	134800	101	8
NATIONAL GYPSUM CO	BURLINGTON	BURLINGTON,NJ	134800	101	8
THE FLINTKOTE CO	CAMDEN	CAMDEN,NJ	134800	101	8
NATIONAL GYPSUM CO	ERIE	CLARENCE CTR,NY	112000	84	6
U.S.GYPSUM CO	GENESSEE	OAKFIELD,NY	112000	84	6
NATIONAL GYPSUM CO	RENSSELAER	RENSSELAEER,NY	112000	84	6
U.S.GYPSUM CO	ROCKLAND	STONY POINT,NY	319000	239	21
GEORGIA-PACIFIC CORP	WESTCHESTER	BUCHANAN,NY	112000	84	6
		TOTAL	1306200	979	77

* ASSUMES NATURAL GAS USE AT ALL PLANTS

INDUSTRY: LIME

FACILITY: LIME PLANTS

EQUIPMENT: LIME KILN

FUEL: COAL(68.15%), NATURAL GAS(25.36%), OIL(4.02%), OTHER(2.37%)

PLANT NAME	COUNTY	LOCATION	1980 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/R	NOX EMISSIONS, TPY
PFIZER INC	LITCHFIELD	CANAAN,CT	19000	163	29
LEE LIME CORP	BERKSHIRE	LEE,MA	90000	770	135
PFIZER INC	BERKSHIRE	ADAMS,MA	90000	770	135
BETHLEHEM STEEL CORP	ERIE	LACKAWANNA,NY	146000	1250	219
ALLIED CHEMICAL CORP	ONONDAGA	SYRACUSE,NY	690000	5906	1035
DOMTAR INDUSTRIES INC	CENTRE	BELLFONTE,PA	112000	959	168
MARBLEHEAD LIME CO	CENTRE	PLEASANT GAP,PA	146000	1250	219
WARNER CO	CENTRE	BELLFONTE,PA	112000	959	168
BETHLEHEM STEEL CORP	LEBANON	ANNVILLE,PA	690000	5906	1035
G.& W.H.CORSON INC	MONTGOMERY	PLYMOUTH MTNG,PA	112000	959	168
		TOTAL	2207000	18892	3311

INDUSTRY: CLAY PRODUCTS

FACILITY: BRICK AND TILE PLANTS

EQUIPMENT: BRICK KILN

FUEL: NATURAL GAS

PLANT NAME	COUNTY	LOCATION	1977 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
MICHAEL KANE BRICK CO INC	MIDDLESEX	MIDDLETOWN,CT	47500	166	6
STILES & HART BRICK CO INC	PLYMOUTH	BRIDGEWATER,MA	115000	405	14
KANE-GONIC BRICK CORP	STRAFFORD	GONIC,NH	47500	166	6
NEW JERSEY SHALE BRICK	SOMERSET	SOMERVILLLE,NJ	115000	405	14
POWELL & MINNOCK BRK WRKS	ALBANY	COEYMANS,NY	145500	509	18
BINGHAM BRICK CO INC	BROOME	BINGHAMPTON,NY	115000	405	14
NASSAU BRICK CO INC	NASSAU	OLD BTHPGE,NY	98000	343	12
GLEN GERY CORP	BERKS	READING,PA	172300	603	22
GLEN GERY CORP	BERKS	SHOEMAKERVILLE,PA	216800	759	27
QUAKERTOWN BRICK & TILE CO	BUCKS	QUAKERTOWN,PA	83200	291	10
HAZLETON BRICK CO INC	LUZERINE	HAZLTON,PA	98000	343	12
GLEN GERY CORP	NORTHCUMBERLAND	WATSONTOWN,PA	172300	603	22
WATSONTOWN BRICK CO INC	NORTHCUMBERLAND	WATSONTOWN,PA	163400	572	20
		TOTAL	1591900	5570	197

INDUSTRY: CLAY PRODUCTS
FACILITY: LIGHT WEIGHT AGGREGATE
EQUIPMENT: ROTARY KILN
FUEL: COAL

PLANT NAME	COUNTY	LOCATION	1980 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
NORLITE CORP	ALBANY	COHES,NY	150000	390	225
		TOTAL	150000	390	225

INDUSTRY: CEMENT

FACILITY: CEMENT CALCINATION

EQUIPMENT: KILN

FUEL:* COAL(93.7%), NATURAL GAS(5.5%), OIL(0.9%)

PLANT NAME	COUNTY	LOCATION	1980 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
ATLANTIC CEMENT	ALBANY	RAVENA,NY	1006000	5935	1308
ALPHA PORTLAND INDUSTRIES	GREENE	CEMENTON,NY	341000	2012	443
LEHIGH PRORTLAND CEMENT CO	GREENE	ALSEN,NY	295000	1741	384
MARQUETTE	GREENE	CATSKILL,NY	392000	2313	510
GLEN FALLS CEMENT	WARREN	GLEN FALLS,NY	314000	1853	408
NATIONAL GYPSUM CO	BERKS	EVANSVILLE,PA	532000	3139	692
PENN-DIXIE INDUSTRIES INC	BUTLER	W.WINFIELD,PA	191000	1127	248
WHITEHALL CEMENT MFG CO	LEHIGH	CEMENTON,PA	490000	2891	637
COPLAY CEMENT	NORTHAMPTON	NAZARETH,PA	617000	3640	802
HERCULES CEMENT CO	NORTHAMPTON	STOCKERTOWN,PA	448000	2643	582
KEYSTONE PORTLAND CEMENT	NORTHAMPTON	BATH,PA	372000	2195	484
LEHIGH PORTLAND CEMENT	NORTHAMPTON	NORTHAMPTON,PA	49000	289	64
LONE STAR INDUSTRIES INC	NORTHAMPTON	NAZARETH,PA	421000	2484	547
MARTIN MARIETTA CORP	NORTHAMPTON	NORTHAMPTON,PA	264000	1558	343
		TOTAL	5047000	29778	6562

* REFLECTS FUEL CONSUMPTION IN THE STUDY AREA

ALL PLANTS USE COAL EXCEPT NATURAL GAS AT THE GLEN FALLS CEMENT PLANT AND OIL AT THE PORTLAND CEMENT PLANT, NORTHAMPTON, PA

INDUSTRY: GLASS

FACILITY: CONTAINER GLASS

EQUIPMENT: MELTING FURNACE

FUEL: NATURAL GAS

PLANT NAME	COUNTY	LOCATION	1980 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
GLASS CONTAINER CORP	WINDHAM	DAYVILLE,CT	170000	1317	552
FOSTER FORBES GLASS	WORCESTER	MILFORD,MA	107100	793	332
BALL GLASS CONTAINER	BERGEN	LYNDHURST,NJ	100600	744	312
METROPACK CONTAINER CO	BERGEN	LYNDHURST,NJ	23200	172	72
BALL GLASS CONTAINER	HUDSON	JERSEY CITY,NJ	100600	744	312
MASDEN IND. INC	HUDSON	NORTH BERGEN,NJ	16800	124	52
OWENS ILLINOIS GLASS	HUDSON	NORTH BERGEN,NJ	205100	1518	636
BALL GLASS CONTAINER	MIDDLESEX	CARTERET,NJ	68400	506	212
BROCKWAY GLASS CO	MONMOUTH	FREEHOLD,NJ	167700	1241	520
MIDLAND GLASS CO	MONMOUTH	CLIFFWOOD,NJ	229600	1699	712
THATCHER GLASS MFG	MORRIS	WARTON,NJ	154800	1146	480
THATCHER GLASS CO	CHEMUNG	ELMIRA,NY	210300	1556	652
LEONE IND OF NY	MONROE	ROCHESTER,NY	27100	201	84
OWENS ILLINOIS GLASS	MONROE	BROCKPORT,NY	160000	1184	496
GLENSHAW GLASS CO	ROCKLAND	ORANGEBURG,NY	73500	544	228
		TOTAL	1822800	13489	5652

INDUSTRY: GLASS

FACILITY: FLAT GLASS PLANTS

EQUIPMENT: MELTING FURNACE

FUEL: NATURAL GAS

PLANT NAME	COUNTY	LOCATION	1977 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
AFG INDUSTRIES INC	BURLINGTON	CINNAMINSON,NJ	122600	2130	490
		TOTAL	122600	2130	490

INDUSTRY: GLASS

FACILITY: PRESSED AND BLOWN GLASS

EQUIPMENT: MELTING FURNACE

FUEL: NATURAL GAS

PLANT NAME	COUNTY	LOCATION	1977 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
CORNING GLASS WORKS INC	CHEMUNG	HORSEHEADS,NY	3800	127	16
SUPER GLASS CORP	KINGS	BROOKLYN,NY	9500	316	40
BAUSCH & LOMB	MONROE	ROCHESTER,NY	7000	233	30
GILLENDER BROS INC	ORANGE	PORT JERVIS,NY	3400	113	14
CORNING GLASS WORKS	ST. LAWRENCE	CANTON,NY	15600	519	66
CORNING GLASS WORKS	CENTRE	STATE COLLEGE,PA	47100	1568	200
OWENS-ILLINOIS INC	LUZERNE	PITTSTON,PA	14100	470	60
SCHOTT OPTICAL GLASS INC	LUZERNE	DURYEA,PA	17300	576	74
GTE SYLVANIA GLASS INC	TIOGA	WELLSBORO,PA	13500	450	57
CORNING GLASS WORKS INC	PROVIDENCE	CENTRAL FALLS,RI	47100	1568	200
		TOTAL	178400	5940	757

INDUSTRY: MINERAL WOOL

FACILITY: MINERAL WOOL

EQUIPMENT: CUPOLA

FUEL: COKE

PLANT NAME	COUNTY	LOCATION	1977 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
U.S. MINERAL PRODUCTS	SUSSEX	STANHOPE,PA	31200	102	42
CELOTEX	LUZERENE	PITTSTON,PA	31200	102	42
BETHLEHEM STEEL CORP	NORTHAMPTON	BETHLEHEM,PA	31200	102	42
BETHLEHEM STEEL CORP	NORTHAMPTON	BETHLEHEM,PA	31200	102	42
		TOTAL	124800	408	168

INDUSTRY: IRON AND STEEL

FACILITY: INTEGRATED PLANTS

EQUIPMENT: SINTER PLANT, COKE OVEN, BLAST FURNACE SOURCES, BASIC OXYGEN FURNACE, ELECTRIC ARC FURNACE, OPEN HEARTH, REHEATING FURNACE, SOAKING PITS, AND CONTINUOUS CASTER

INTEGRATED FUEL: BLAST FURNACE GAS(39.05%), NATURAL GAS(36.63%), COKE OVEN GAS(16.85%), FUEL OIL(6.21%), AND TAR AND PITCH(1.25%)

MERCHANT COKE
PLANT FUEL: COKE OVEN GAS(100%)

PLANT NAME	COUNTY	LOCATION	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
BETHLEHEM STEEL CORP	ERIE	LACKAWANNA,NY	23279	6122
REPUBLIC STEEL CO	ERIE	BUFFALO,NY	4225	858
BETHLEHEM STEEL CORP	NORTHAMPTON	BETHLEHEM,PA	13646	4186
U.S. STEEL CORP	BUCKS	FAIRLESS HILLS,PA	23940	10640
BETHLEHEM STEEL CORP	DAUPHIN	STEELTON,PA	3635	997
DONNER-HANNA	ERIE	BUFFALO,NY	1944	593
TONAWANDA COKE	ERIE	BUFFALO,NY	691	211
ALABAMA BYPROD	MONTGOMERY	SWEDELAND,PA	921	281
		TOTAL	72281	23888

NOTE: ESTIMATED PRODUCTION INDICATES THE SUM OF ALL PRODUCT STREAMS

ENERGY CONSUMPTION, 10E6 BTU/TON	0.29	3.10	1.90	0.20	0.10	3.30	1.40	0.10	2.00
NOX EMISSION FACTOR, LB/TON	1.00	1.09	0.34		0.01	4.50	0.80		1.10

CAPACITY,
10E6 TPY

PLANT NAME	LOCATION	SINTER PLANT	COKE PLANT	BF STOVES	BOF	ELECTRIC FURNACE	OPEN HEARTH	SOAKING PITS	CONT. CASTER	REHEAT FURNACE
BETHLEHEM STEEL CORP	LACKAWANNA,NY	1.46	1.70	4.56	4.70	0.00	0.00	6.30	0.00	5.20
BETHLEHEM STEEL CORP	BETHLEHEM,PA	2.40	2.00	3.87	2.70	0.33	0.00	2.20	0.90	1.12
REPUBLIC STEEL CO	BUFFALO,NY	0.00	0.00	1.16	1.00	0.00	0.00	0.90	0.00	1.30
U.S. STEEL CORP	FAIRLESS,PA	2.63	1.00	3.00	0.00	0.58	3.60	1.10	0.60	6.20
BETHLEHEM STEEL CORP	STEELTON,PA	0.00	0.00	0.00	0.00	0.69	0.00	0.80	0.00	2.10
DONNER-HANNA	BUFFALO,NY	0.00	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TONAWANDA COKE	BUFFALO,NY	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALABAMA BYPROD	SWEDELAND,PA	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	6.49	6.40	12.59	8.40	1.60	3.60	11.30	1.50	15.92

PRODUCTION,
10E3 TPY

PLANT NAME	LOCATION	SINTER PLANT	COKE PLANT	BF STOVES	BOF	ELECTRIC FURNACE	OPEN HEARTH	SOAKING PITS	CONT. CASTER	REHEAT FURNACE
BETHLEHEM STEEL CORP	LACKAWANNA,NY	985	1146	3075	3170	0	0	4249	0	3507
BETHLEHEM STEEL CORP	BETHLEHEM,PA	1619	1349	2610	1821	223	0	1484	607	755
REPUBLIC STEEL CO	BUFFALO,NY	0	0	782	674	0	0	607	0	877
U.S. STEEL CORP	FAIRLESS,PA	1774	674	2023	0	391	2428	742	405	4181
BETHLEHEM STEEL CORP	STEELTON,PA	0	0	0	0	465	0	540	0	1416
DONNER-HANNA	BUFFALO,NY	0	627	0	0	0	0	0	0	0
TONAWANDA COKE	BUFFALO,NY	0	223	0	0	0	0	0	0	0
ALABAMA BYPROD	SWEDELAND,PA	0	297	0	0	0	0	0	0	0
	TOTAL	4378	4316	8490	5665	1079	2428	7622	1012	10736

ENERGY,
10E9 BTU/YR

PLANT NAME	LOCATION	SINTER PLANT	COKE PLANT	BF STOVES	BOF	ELECTRIC FURNACE	OPEN HEARTH	SOAKING PITS	CONT. CASTER	REHEAT FURNACE
BETHLEHEM STEEL CORP	LACKAWANNA,NY	286	3553	5843	634	0	0	5949	0	7014
BETHLEHEM STEEL CORP	BETHLEHEM,PA	470	4182	4959	364	22	0	2078	61	1510
REPUBLIC STEEL CO	BUFFALO,NY	0	0	1486	135	0	0	850	0	1754
U.S. STEEL CORP	FAIRLESS,PA	514	2089	3844	0	39	8012	1039	41	0362
BETHLEHEM STEEL CORP	STEELTON,PA	0	0	0	0	47	0	756	0	2832
DONNER-HANNA	BUFFALO,NY	0	1944	0	0	0	0	0	0	0
TONAWANDA COKE	BUFFALO,NY	0	691	0	0	0	0	0	0	0
ALABAMA BYPROD	SWEDELAND,PA	0	921	0	0	0	0	0	0	0
	TOTAL	1270	13380	16132	1133	108	8012	10672	102	21472

EMISSIONS,
TPY

PLANT NAME	LOCATION	SINTER PLANT	COKE PLANT	BF STOVES	BOF	ELECTRIC FURNACE	OPEN HEARTH	SOAKING PITS	CONT. CASTER	REHEAT FURNACE
BETHLEHEM STEEL CORP	LACKAWANNA,NY	887	1083	523	0	0	0	1700	0	1929
BETHLEHEM STEEL CORP	BETHLEHEM,PA	1457	1275	444	0	1	0	594	0	415
REPUBLIC STEEL CO	BUFFALO,NY	0	0	133	0	0	0	243	0	482
U.S. STEEL CORP	FAIRLESS,PA	1597	637	344	0	2	5463	297	0	2300
BETHLEHEM STEEL CORP	STEELTON,PA	0	0	0	0	2	0	216	0	779
DONNER-HANNA	BUFFALO,NY	0	593	0	0	0	0	0	0	0
TONAWANDA COKE	BUFFALO,NY	0	211	0	0	0	0	0	0	0
ALABAMA BYPROD	SWEDELAND,PA	0	281	0	0	0	0	0	0	0
	TOTAL	3941	4080	1444	0	5	5463	3050	0	5985

INDUSTRY: IRON AND STEEL

FACILITY: IRON FOUNDRIES

EQUIPMENT: CUPOLA

FUEL: COKE

PLANT NAME	COUNTY	LOCATION	1976 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
PRODUCTO MACHINE COMPANY	FAIRFIELD	BRIDGEPORT,CT	31250	106	2
SUPERIOR CASTINGS CORP	FAIRFIELD	NORWALK,CT	31250	106	2
WHITE CONSOLIDATED IND INC	FAIRFIELD	BRIDGEPORT,CT	31250	106	2
CONNECTICUT FOUNDRY CO	HARTFORD	ROCKYHILL,CT	31250	106	2
PLAINVILLE CASTING CO	HARTFORD	PLAINVILLE,CT	31250	106	2
TURNER & SEYMOUR MFG CO	LITCHFIELD	TORRINGTON,CT	31250	106	2
U.S.M. CORP	ESSEX	BEVERLY,MA	31250	106	2
H.B. SMITH CO INC	HAMPDEN	WESTFIELD,MA	31250	106	2
JAHN FOUNDRY CORP	HAMPDEN	SPRINGFIELD,MA	263940	892	16
PLAINVILLE CASTING CORP	HAMPDEN	WESTFIELD,MA	31250	106	2
SPRINGFIELD FOUNDRY CO INC	HAMPDEN	INDIAN ORCHARD,MA	31250	106	2
BRIDGEWATER FOUNDRY CO INC	PLYMOUTH	BRIDGEWATER,MA	31250	106	2
E.L. LEBARON FOUNDRY CO	PLYMOUTH	BROCKTON,MA	31250	106	2
CHAS G. ALLEN CO	WORCESTER	BARRE,MA	31250	106	2
FITCHBURG FOUNDRY INC	WORCESTER	FITCHBURG,MA	31250	106	2
HERSEY PRODUCTS INC	WORCESTER	GILBERTVILLE,MA	31250	106	2
ABEX CORP	BERGEN	MAHWAH,NJ	263940	892	16
AMSTED INDUSTRIES INC	BURLINGTON	FLORENCE,NJ	263940	892	16
FLOCKHART FOUNDRY CO	ESSEX	NEWARK,NJ	31250	106	2
CAMPBELL FOUNDRY CO	HUDSON	HARRISON,NJ	31250	106	2
NORTH JERSEY FOUNDRY CO	PASSAIC	LITTLE FALLS,NJ	31250	106	2
ATLANTIC STATES	WARREN	PHILLIPSBURGH,NJ	31250	106	2
MALLER INDUSTRIES INC	ALLEGANY	FRIENDSHIP,NY	31250	106	2
SHEPARD NILES CRN & HOIST	CHEMUNG	ELMIRA,NY	31250	106	2

INDUSTRY: IRON AND STEEL

FACILITY: IRON FOUNDRIES

EQUIPMENT: CUPOLA

FUEL: COKE

PLANT NAME	COUNTY	LOCATION	1976 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
BUFFALO FORGE CO	ERIE	BUFFALO,NY	31250	106	2
GENERAL MOTORS CORP	ERIE	BUFFALO,NY	263940	892	16
IRONWORTH-WORTHINGTON GRP	ERIE	BUFFALO,NY	31250	106	2
WORMUTH BROS FOUNDRY INC	GREENE	ATHENS,NY	31250	106	2
GLEASON WORKS INC	MONROE	ROCHESTER,NY	31250	106	2
UTICA RADIATOR CORP	ONEIDA	UTICA,NY	31250	106	2
CROUSE-HINDS CO	ONONDAGA	SYRACUSE,NY	263940	892	16
STANTON FOUNDRY INC	ONONDAGA	SOLVAY,NY	31250	106	2
GENEVA FOUNDRY CORP	ONTARIO	GENEVA,NY	31250	106	2
ABEX CORP	ORLEANS	MEDINA,NY	31250	106	2
BLACK-CLAWSON CO INC	SARATOGA	WATERTOWN,NY	31250	106	2
INGERSOLL-RAND CO	TIOGA	WAVERLY,NY	263940	892	16
TIOGA FOUNDRY CORP	TIOGA	OWEGO,NY	31250	106	2
CONFER SMITH & CO INC	BERKS	HAMBURG,PA	31250	106	2
EASTERN FOUNDRY INC	BERKS	BOYERTOWN,PA	31250	106	2
HOFMAN INDUSTRIES INC	BERKS	SINKING SPRING,PA	31250	106	2
O Z GEDING CO	BERKS	SHOEMAKERSVILLE,PA	31250	106	2
READING GREY IRON CST INC	BERKS	READING,PA	31250	106	2
ROCKWELL INTERNTNL CORP	BERKS	READING,PA	263940	892	16
BENTON FOUNDRY INC	COLUMBIA	BENTON,PA	31250	106	2
BETHLEHEM STEEL CORP	DAUPHIN	STEELTON,PA	31250	106	2
EAST PENN FOUNDRY CO	LEHIGH	MACUNGIE,PA	31250	106	2
GENERAL MACHINE CORP	LEHIGH	EMMAUS,PA	31250	106	2

INDUSTRY: IRON AND STEEL

FACILITY: IRON FOUNDRIES

EQUIPMENT: CUPOLA

FUEL: COKE

PLANT NAME	COUNTY	LOCATION	1976 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
INGERSOLL-RAND CO	LEHIGH	ALLENTOWN,PA	31250	106	2
KLINE FOUNDRIES	LEHIGH	ALBURTIS,PA	31250	106	2
UNITED FOUNDRIES INC	LUZERNE	WYOMING,PA	31250	106	2
ANCHOR/DARLING VALVE CO	LYCOMING	WILLIAMSPORT,PA	31250	106	2
KOPPERS CO INC	LYCOMING	MUNCY,PA	31250	106	2
KULP FOUNDRY INC	MONROE	E STROUDSBURG,PA	31250	106	2
PONONO FOUNDRY INC	MONROE	STROUDSBURG,PA	31250	106	2
HALE FIRE PUMP CO	MONTGOMERY	CONSHOHOCKEN,PA	31250	106	2
KEYSTONE GREY IRON FNDR CO	MONTGOMERY	POTTSTOWN,PA	31250	106	2
DIETERS FOUNDRY CO	NORTHAMPTON	CHERRYVILLE,PA	31250	106	2
WATSONTOWN FOUNDRY CO INC	NORTHCUMBERLAND	WATSONTOWN,PA	31250	106	2
HALLSTEAD FOUNDRY INC	SUSQUEHANNA	HALLSTEAD,PA	31250	106	2
J P WARD FOUNDRIES INC	TIOGA	BLOSSBURG,PA	263940	892	16
NARRAGANSETT GREY IRN FDRY	PROVIDENCE	ESMOND,RI	31250	106	2
SEABOARD FOUNDRY INC	PROVIDENCE	JOHNSTON,RI	31250	106	2
LACONIA MALLEABLE IRON CO	BELKNAP	LACONIA,NH	31250	106	2
STANLEYG FLAGG & CO INC	MONTGOMERY	STOWE,PA	263940	892	16
		TOTAL	4094210	13858	254

INDUSTRY: IRON AND STEEL

FACILITY: MINI AND MIDI STEEL PLANTS

EQUIPMENT: SOAKING PITS AND REHEATING FURNACES

FUEL: FUEL OIL(13.7%), NATURAL GAS(86.3%)

PLANT NAME	COUNTY	LOCATION	ENERGY CONSUMPTION, 10E9 BTU/YR	NOX EMISSIONS, TPY
CARPENTER TECHNOLOGY CORP	FAIRFIELD	BRIDGEPORT,CT	180	51 *
YALE STEEL CO	NEW HAVEN	WILLINGFORD,CT	321	90 *
NEW JERSEY STEEL & STRCTL	MIDDLESEX	SAYREVILLE,NJ	310	85
RARITAN RIVER STEEL	MIDDLESEX	PERTH AMBOY,NJ	674	185
AL TECH SPECIALITY STEEL	ALBANY	WATERVLIET,NY	302	83
AUBURN STEEL CO	CAYUGA	AUBURN,NY	337	93
ALLEGHENY LUDLUM IND	ONEIDA	NEW HARTFORD,NY	54	15
CRUCIBLE INC	ONONDAGA	SYRACUSE,NY	54	15
CARPENTER TECHNOLOGY CORP	BERKS	READING,PA	148	41
CECO CORP, MILTON MFG	NORTHCUMBERLAND	MILTON,PA	175	48
WASHBURN WIRE CO	PROVIDENCE	PHILLIPSDALE,RI	81	22
		TOTAL	2636	728

* INDICATES PLANTS WITH SOAKING PITS AND REHEATING FURNACES, OTHER PLANTS CONTAIN REHEATING OPERATIONS ONLY

PERCENT EMISSIONS ATTRIBUTABLE TO SOAKING PITS AND REHEATING FURNACES ARE RESPECTIVELY: 63 AND 37 FOR CARPENTER TECHNOLOGY CORP PLANT, 42 AND 58 FOR YALE STEEL CO PLANT, AND 31 AND 69 FOR BETHLEHEM STEEL CORP PLANT

I136N

INDUSTRY: SECONDARY NONFERROUS METALS

FACILITY: ALUMINUM SMELTER

EQUIPMENT: SWEATING FURNACE AND REVERBERATORY FURNACE

FUEL: NATURAL GAS(75%), OIL(25%)

PLANT NAME	COUNTY	LOCATION	1980 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	* NOX EMISSIONS, TPY
CHARLES BATCHELDER CO	FAIRFIELD	BOTSFORD,CT	8900	482	2
THE HIMMEL BROS CO	HARTFORD	HARTFORD,CT	8900	482	2
INFELD METALS CO	NEW HAVEN	WATERBURRY,CT	8900	482	2
ASARCO	MIDDLESEX	PERTH AMBOY,NJ	8900	482	2
ALUMINUM BILLETS INC	MIDDLESEX	SOUTH AMBOY,NJ	8900	482	2
BADGER ALMNM EXTRSN CORP	KINGS	BROOKLYN,NY	8900	482	2
BELMONT SMLTNG & RFNG INC	KINGS	BROOKLYN,NY	8900	482	2
J.R. ELKINS INC	KINGS	BROOKLYN,NY	8900	482	2
HENNINGS BROS & SMITH INC	KINGS	BROOKLYN,NY	8900	482	2
ROCHESTER SMLTNG & RFNG	MONROE	ROCHESTER,NY	8900	482	2
ROTH BROS SMELTING CORP	ONONDAGA	E. SYRACUSE,NY	8900	482	2
PARAGON SMELTING CORP	QUEENS	LONG ISLAND,NY	8900	482	2
ALCAN-BARR ALUMINUM CO	LEBANON	PALMYRA,PA	8900	482	2
		TOTAL	115700	6266	26

* PERCENT NOX EMISSIONS ATTRIBUTABLE TO SWEATING FURNACE AND REVERBERATORY FURNACE : 66.0 AND 34.0 RESPECTIVELY

INDUSTRY: SECONDARY NONFERROUS METALS

FACILITY: COPPER SMELTING AND REFINING

EQUIPMENT: SWEATING FURNACE, BLAST FURNACE, REVERBERATORY FURNACES (ONE FOR SMELTING AND ONE FOR REFINING)

FUEL: COKE(89%), OIL(2%), COAL(2%), AND NATURAL GAS(7%)

PLANT NAME	COUNTY	LOCATION	1980 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	* NOX EMISSIONS, TPY
BRISTOL BRASS CORP	HARTFORD	BRISTOL,CT	11000	100	41
INTERNATIONAL WIRE PRDCTS	BERGEN	WYCKOFF,NJ	11000	100	41
CIRCUIT FOIL CORP	BURLINGTON	BORDERTOWN,NJ	11000	100	41
BARTH SMLTNG & RFNG	ESSEX	NEWARK,NJ	11000	100	41
FEDERATED METALS	ESSEX	NEWARK,NJ	11000	100	41
NASSAU SMLTNG & RFNG	ESSEX	NEWARK,NJ	11000	100	41
WILBUR B DRIVER CO	ESSEX	NEWARK,NJ	11000	100	41
U.S. METALS REFINING CO	MIDDLESEX	CARTARET,NJ	65000	593	245
ABBEY METAL	MORRIS	DOVER,NJ	11000	100	41
KEARNEY SMELTING	SOMMERSET	BELLE-MEAD,NJ	11000	100	41
BELMONT SMLTNG & RFNG	KINGS	BROOKLYN,NY	11000	100	41
SAMUEL GREENFIELD	KINGS	BROOKLYN,NY	11000	100	41
ROTH BROS SMLTNG CORP	ONONDAGA	E. SYRACUSE,NY	11000	100	41
SEMI-ALLOYS INC	WESTCHESTER	MT. VERNON,NY	11000	100	41
PARAGON SMELTING CORP	QUEENS	LONG ISLAND,NY	11000	100	41
ELECTRIC MATERIALS INC	ERIE	ERIE,PA	11000	100	41
KAWECKI BERYKO INDUSTRY	BERKS	READING,PA	11000	100	41
CERRO METAL PRODUCTS	CENTRE	BELLEFONTE,PA	11000	100	41
NEW JERSEY ZINC CO	NORTHAMPTON	BETHLEHEM,PA	11000	100	41
		TOTAL	263000	2393	983

* PERCENT NOX EMISSIONS ATTRIBUTABLE TO SWEATING FURNACE, BLAST FURNACE, SMELTING REVERBERATORY FURNACE, AND REFINING REVERBERATORY FURNACE ARE 1.4, 8.0, 81.4, AND 9.2, RESPECTIVELY

INDUSTRY: SECONDARY NONFERROUS METALS

FACILITY: LEAD SMELTER

EQUIPMENT: BLAST FURNACE AND REVERBERATORY FURNACE

FUEL: COKE(26%), NATURAL GAS(56%), FUEL OIL(18%)

PLANT NAME	COUNTY	LOCATION	1980 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	* NOX EMISSIONS, TPY
ESSEX METALS ALLOYS	MIDDLESEX	NEWARK,NJ	4600	15	3
FEDERATED METALS	ESSEX	NEWARK,NJ	4600	15	3
DELCO REMY	MIDDLESEX	NEW BRUNSWICK,NJ	4600	15	3
REPUBLIC METALS ALLOYS INC	KINGS	BROOKLYN,NY	4600	15	3
ROTH BROS SMELTING CORP	ONONDAGA	EAST SYTACUSE,NY	1340	4	1
RSR	ULSTER	WALLKILL,NY	4600	15	3
EAST PENN MFG CO	BERKS	LYON STATION,PA	7236	23	5
GENERAL BATTERY CORP	BERKS	READING,PA	30820	99	21
TONNOLLI CORP	CARBON	NESQUEHONING,PA	26800	86	18
		TOTAL	89196	287	60

* PERCENT NOX EMISSIONS ATTRIBUTABLE TO BLAST FURNACE AND REVERBERATORY FURNACE ARE 23.6 AND 76.4, RESPECTIVELY

INDUSTRY: PRIMARY ALUMINUM FABRICATION

FACILITY: SHEET, PLATE, AND FOIL

EQUIPMENT: REVERBERATORY MELTING FURNACE AND HEAT TREATING FURNACE

FUEL: NATURAL GAS(95.5%) AND OIL(4.5%)

PLANT NAME	COUNTY	LOCATION	1977 ESTIMATED PRODUCTION, TPY	ENERGY CONSUMPTION, 10E9 BTU/YR	‡ NOX EMISSIONS, TPY
NATIONAL ALUMINUM	NEW HAVEN	DANBURY,CT	51500	1267	153
THIN SHEET METAL CO	NEW HAVEN	WATERBURY,CT	51500	1267	153
UNITED ALUMINUM CORP	NEW HAVEN	NORTH HAVEN,CT	51500	1267	153
STRANAHAN FOIL CO INC	BERGEN	S. HACKENSACK,NJ	51500	1267	153
LEVOLOR LORENTZEN INC	HUDSON	HOBOKEN,NJ	51500	1267	153
EASTERN RLNG MILLS INC	BRONX	BRONX,NY	51500	1267	153
ALCAN SHEET AND PLATE	OSWEGO	OSWEGO,NY	51500	1267	153
GENERAL ELECTRIC CO	WASHINGTON	HUDSON FALLS,NY	51500	1267	153
RODNEY METALS INC	BRISTOL	NEW BEDFORD,MA	51500	1267	153
ALCOA	LEBANON	LEBANON,PA	51500	1267	153
		TOTAL	515000	12670	1530

‡ PERCENT NOX EMISSIONS ATTRIBUTABLE TO REVERBERATORY FURNACE AND HEAT TREATING FURNACE ARE 46.3 AND 53.7, RESPECTIVELY

PART 2

INDUSTRIAL BOILERS

ESTIMATED FUEL CONSUMPTION
INDUSTRIAL BOILERS > 250 MILLION BTU/H
IN 150-COUNTY STUDY AREA
PN 3450-78

STATE	COUNTY	SIC CODE	COAL 1000 TONS	RESID OIL 1000 BBL	DIST OIL 1000 BBL	NAT GAS 1000 MCF	COKE OVEN 1000 MCF	BLAST FUR 1000 MCF
CONN.	HARTFORD	UNK		5				
	HARTFORD	37		303				
	LITCHFIELD	UNK		12				
	NEW HAVEN	34		62				
	NEW HAVEN	97		400				
	NEW HAVEN	28		260				
	FUEL TOTAL		0	1041	0	0	0	0
	TRILLION BTU'S		0.00	6.56	0.00	0.00	0.00	0.00
MASS.	ESSEX	37		59		1163		
	ESSEX	UNK		19				
	ESSEX	49		1		2527		
	FUEL TOTAL		0	79	0	3690	0	0
	TRILLION BTU'S		0.00	0.50	0.00	3.78	0.00	0.00
N.H.	COOS	26		316				
	ROCKINGHAM	97		0				
	FUEL TOTAL		0	316	0	0	0	0
	TRILLION BTU'S		0.00	1.99	0.00	0.00	0.00	0.00
N.J.	MIDDLESEX	28		438				
	MIDDLESEX	29		36				
	MIDDLESEX	29		158		177		
	MIDDLESEX	28		552				
	MORRIS	UNK		4				
	MORRIS	26		800				
	PASSAIC	26		236				
	SOMERSET	UNK		7				
	FUEL TOTAL		0	2231	0	177	0	0
	TRILLION BTU'S		0.00	14.05	0.00	0.18	0.00	0.00
N.Y.	ERIE	33		524	0	1340		
	ERIE	33		933		5461		
	ESSEX	26		619				
	MONROE	38	1165	729				
	NEW YORK	20		171				
	NEW YORK	49		1266				
	ONEIDA	97		15				
	ONANDAGA	28	138		115			
	OSWEGO	20		930				
	QUEENS	49		254				
	RICHMOND	28		265		219		
	ST. LAWRENCE	33		1126				
	SARATOGA	26		338				
	SCHENECTADY	35		540	172			
	WESTCHESTER	20			271			
	FUEL TOTAL		1303	7710	559	7020	0	0
	TRILLION BTU'S		33.89	48.57	3.26	7.19	0.00	0.00
PENN	BUCKS	33		205			4188	96260
	CLINTON	26	188					
	MONTGOMERY	33		52			323	10495
	NORTHAMPTON	33		527			2486	50662
	FUEL TOTAL		188	784	0	0	6997	157417
	TRILLION BTU'S		4.88	4.94	0.00	0.00	3.85	14.80
R.I.	PROVIDENCE	22		24				
	WASHINGTON	22		60				
	FUEL TOTAL		0	84	0	0	0	0
	TRILLION BTU'S		0.00	0.53	0.00	0.00	0.00	0.00
TOTAL FUEL - ALL STATES			1491	12245	559	10887	6997	157417
FUEL CONSUMPTION, TRILLION BTU'S			38.77	77.14	3.26	11.15	3.85	14.80

CALCULATED NOX EMISSIONS BY FUEL TYPE
INDUSTRIAL BOILERS > 250 MILLION BTU/H
IN 150-COUNTY STUDY AREA
PN 3450-78

			NOX EMISSIONS (TONS PER YEAR) BY FUEL TYPE						
STATE	COUNTY	SIC CODE	COAL	RESID OIL	DIST OIL	NAT GAS	COKE OVEN	BLAST FUR	TOTAL
CONN.	HARTFORD	UNK		5					5
	HARTFORD	37		351					351
	LITCHFIELD	UNK		14					14
	NEW HAVEN	34		71					71
	NEW HAVEN	97		462					462
	NEW HAVEN	28		301					301
	NOX TOTAL		0	1204	0	0	0	0	1204
MASS.	ESSEX	37		68		320			388
	ESSEX	UNK		22					22
	ESSEX	49		1		695			696
	NOX TOTAL		0	91	0	1015	0	0	1106
N.H.	COOS	26		365					365
	ROCKINGHAM	97		0					0
	NOX TOTAL		0	365	0	0	0	0	365
N.J.	MIDDLESEX	28		506					506
	MIDDLESEX	29		59					59
	MIDDLESEX	29		182		12			195
	MIDDLESEX	28		637					637
	MORRIS	UNK		4					4
	MORRIS	26		924					924
	PASSAIC	26		272					272
	SOMERSET	UNK		8					8
	NOX TOTAL		0	2593	0	12	0	0	2606
N.Y.	ERIE	33		605	0	370			975
	ERIE	33		1076		1501			2577
	ESSEX	26		715					715
	MONROE	38	21533	1060					22593
	NEW YORK	20		198					198
	NEW YORK	49		1462					1462
	ONEIDA	97		33					33
	ONANDAGA	28	1452		49				1501
	OSWEGO	20		1076					1076
	QUEENS	49		293					293
	RICHMOND	28		306		15			321
	ST. LAWRENCE	33		1304					1304
	SARATOGA	26		391					391
	SCHENECTADY	35		624	72				696
	WESTCHESTER	20			114				114
	NOX TOTAL		22985	9143	235	1886	0	0	34249
PENN.	BUCKS	33		237			168	1107	1511
	CLINTON	26	1316						1316
	MONTGOMERY	33		66			13	121	200
	NORTHAMPTON	33		609			99	583	1291
	NOX TOTAL		1316	911	0	0	280	1810	4317
R.I.	PROVIDENCE	22		28					28
	WASHINGTON	22		69					69
	NOX TOTAL		0	97	0	0	0	0	97
TOTAL NOX - ALL STATES			24301	14405	235	2913	280	1810	43944

PART 3

TRANSPORTATION, RESIDENTIAL AND COMMERCIAL SECTORS

STATE/COUNTY	ENERGY CONSUMPTION, 10E12 BTU/YR			NOX EMISSIONS, TPY			LAND AREA SQ.ML	ENERGY DENSITY, 10E12BTU/ YR-SQ.ML	EMISSION DENSITY, TPY/SQ.ML	EMN/ENR COEFF.
	GASOLINE	DIESEL	TOTAL	GASOLINE	DIESEL	TOTAL				
CONNECTICUT	156.04	14.21	170.25	56173	15561	71734	4863	0.04	14.75	421.34
FAIRFIELD	41.55	3.78	45.34	14959	4144	19103	626	0.07	30.52	421.34
HARTFORD	41.20	3.75	44.95	14831	4108	18939	739	0.06	25.63	421.33
LITCHFIELD	8.73	0.80	9.53	3143	871	4014	925	0.01	4.34	421.39
MIDDLESEX	7.01	0.64	7.64	2522	699	3221	372	0.02	8.66	421.39
NEW HAVEN	36.00	3.28	39.28	12960	3590	16550	604	0.07	27.40	421.34
NEW LONDON	11.53	1.05	12.58	4150	1150	5300	667	0.02	7.95	421.37
TOLLAND	5.46	0.50	5.95	1964	544	2508	416	0.01	6.03	421.36
WINDHAM	4.57	0.42	4.98	1644	455	2099	514	0.01	4.08	421.32
MASSACHUSETTS	269.91	19.69	289.60	97165	21553	118718	7283	0.04	16.30	409.94
BERKSHIRE	7.22	0.53	7.74	2598	576	3174	941	0.01	3.37	409.84
BRISTOL	23.27	1.70	24.97	8377	1858	10235	554	0.05	18.47	409.94
ESSEX	32.86	2.40	35.26	11829	2624	14453	494	0.07	29.26	409.95
FRANKLIN	3.47	0.25	3.72	1249	277	1526	708	0.01	2.16	409.89
HAMPDEN	22.01	1.61	23.62	7925	1758	9683	619	0.04	15.64	409.96
HAMPSHIRE	6.49	0.47	6.97	2337	518	2855	529	0.01	5.40	409.89
MIDDLESEX	69.38	5.06	74.44	24978	5541	30519	825	0.09	36.99	409.96
NORFOLK	31.23	2.28	33.51	11244	2494	13738	394	0.09	34.87	409.94
PLYMOUTH	20.98	1.53	22.51	7552	1675	9227	654	0.03	14.11	409.94
SUFFOLK	20.76	1.51	22.28	7474	1658	9132	56	0.40	163.07	409.94
WORCHESTER	32.23	2.35	34.58	11602	2574	14176	1509	0.02	9.39	409.95
NEW HAMPSHIRE	47.31	3.89	51.20	17032	4258	21290	9028	0.01	2.36	415.83
BELKNAP	2.46	0.20	2.66	885	221	1106	400	0.01	2.77	415.66
CARROL	1.72	0.14	1.87	621	155	776	938	0.00	0.83	415.68
CHESHIRE	3.04	0.25	3.29	1095	274	1369	715	0.00	1.91	416.05
COOS	1.59	0.13	1.72	571	143	714	1820	0.00	0.39	416.10
GRAFTON	3.31	0.27	3.58	1191	298	1489	1732	0.00	0.86	415.92
HILLSBOROUGH	14.65	1.20	15.86	5275	1319	6594	887	0.02	7.43	415.84
MERRIMACK	4.70	0.39	5.09	1693	423	2116	930	0.01	2.28	415.66
ROCKINGHAM	10.35	0.85	11.21	3728	932	4660	691	0.02	6.74	415.84
STRAFFORD	3.82	0.31	4.14	1376	344	1720	376	0.01	4.57	415.82
SULLIVAN	1.66	0.14	1.79	597	149	746	539	0.00	1.38	415.70
NEW JERSEY	329.79	39.42	369.21	118725	43158	161883	5270	0.07	30.72	438.46
BERGEN	48.71	5.82	54.54	17537	6375	23912	234	0.23	102.19	438.45
BURLINGTON	18.91	2.26	21.17	6807	2474	9281	819	0.03	11.33	438.46
ESSEX	34.73	4.15	38.88	12504	4546	17050	130	0.30	131.15	438.48
HUDSON	20.21	2.42	22.62	7274	2644	9918	47	0.48	211.02	438.46
HUNTERDON	5.49	0.66	6.15	1977	719	2696	423	0.01	6.37	438.51
MERCER	17.57	2.10	19.67	6325	2299	8624	228	0.09	37.82	438.42
MIDDLESEX	32.94	3.94	36.88	11858	4311	16169	312	0.12	51.82	438.45
MONMOUTH	28.51	3.41	31.92	10263	3731	13994	476	0.07	29.40	438.46
MORRIS	24.56	2.94	27.49	8841	3214	12055	468	0.06	25.76	438.45
OCEAN	19.37	2.31	21.68	6972	2534	9506	642	0.03	14.81	438.45
PASSAIC	24.30	2.90	27.20	8748	3180	11928	192	0.14	62.13	438.47
SOMERSET	10.32	1.23	11.56	3717	1351	5068	307	0.04	16.51	438.50
SUSSEX	6.70	0.80	7.50	2413	877	3290	527	0.01	6.24	438.46
UNION	32.29	3.86	36.15	11623	4225	15848	103	0.35	153.86	438.44
WARREN	5.18	0.62	5.80	1866	678	2544	362	0.02	7.03	438.36

STATE/COUNTY	ENERGY CONSUMPTION, 10E12 BTU/YR			NOX EMISSIONS, TPY			LAND AREA SQ.ML	ENERGY DENSITY, 10E12BTU/ YR-SQ.ML	EMISSION DENSITY, TPY/SQ.ML	EMN/ENR COEFF.
	GASOLINE	DIESEL	TOTAL	GASOLINE	DIESEL	TOTAL				
NEW YORK	632.46	43.13	675.59	227684	47224	274908	44908	0.02	6.12	406.91
ALBANY	12.35	0.84	13.19	4445	922	5367	526	0.03	10.20	406.91
ALLEGANY	2.23	0.15	2.38	801	166	967	1047	0.00	0.92	406.85
BRONX	18.23	1.24	19.48	6564	1361	7925	41	0.48	193.29	406.89
BROOME	10.64	0.73	11.37	3831	795	4626	714	0.02	6.48	406.98
CAYUGA	3.60	0.25	3.84	1295	269	1564	698	0.01	2.24	407.04
CHEMUNG	4.44	0.30	4.74	1599	332	1931	415	0.01	4.65	407.01
CHENANGO	2.48	0.17	2.65	893	185	1078	903	0.00	1.19	406.87
CLINTON	3.33	0.23	3.56	1200	249	1449	1059	0.00	1.37	407.10
COLUMBIA	3.17	0.22	3.39	1142	237	1379	645	0.01	2.14	406.88
CORTLAND	2.17	0.15	2.31	780	162	942	502	0.00	1.88	407.08
DELAWARE	2.37	0.16	2.53	854	177	1031	1443	0.00	0.71	406.87
DUTCHESS	12.63	0.86	13.49	4546	943	5489	813	0.02	6.75	406.94
ERIE	45.42	3.10	48.52	16352	3391	19743	1058	0.05	18.66	406.91
ESSEX	1.93	0.13	2.06	693	144	837	1823	0.00	0.46	406.81
FRANKLIN	2.11	0.14	2.26	761	158	919	1674	0.00	0.55	406.96
FULTON	2.42	0.16	2.58	870	181	1051	498	0.01	2.11	406.90
GENESEE	3.12	0.21	3.33	1124	233	1357	501	0.01	2.71	406.93
GREENE	2.46	0.17	2.63	885	184	1069	653	0.00	1.64	407.10
HAMILTON	0.28	0.02	0.30	102	21	123	1735	0.00	0.07	405.71
HERKIMER	3.03	0.21	3.24	1092	226	1318	1435	0.00	0.92	406.74
JEFFERSON	4.25	0.29	4.54	1531	318	1849	1294	0.00	1.43	407.01
KINGS	33.67	2.30	35.97	12121	2514	14635	70	0.51	209.07	406.91
LEWIS	1.21	0.08	1.30	437	91	528	1291	0.00	0.41	407.13
LIVINGSTON	2.88	0.20	3.08	1038	215	1253	638	0.00	1.96	406.65
MADISON	3.24	0.22	3.46	1167	242	1409	661	0.01	2.13	406.86
MONROE	34.01	2.32	36.33	12243	2539	14782	675	0.05	21.90	406.91
MONTGOMERY	2.80	0.19	3.00	1010	209	1219	408	0.01	2.99	406.90
NASSAU	73.10	4.99	78.09	26317	5458	31775	289	0.27	109.95	406.92
NEW YORK	16.19	1.10	17.29	5828	1209	7037	23	0.75	305.96	406.90
ONEIDA	11.90	0.81	12.71	4283	888	5171	1223	0.01	4.23	406.91
ONONDAGA	21.80	1.49	23.29	7849	1628	9477	794	0.03	11.94	406.94
ONTARIO	4.43	0.30	4.73	1595	331	1926	651	0.01	2.96	407.00
ORANGE	13.42	0.92	14.34	4832	1002	5834	833	0.02	7.00	406.87
ORLEANS	1.95	0.13	2.08	701	145	846	396	0.01	2.14	406.65
OSWEGO	5.29	0.36	5.65	1904	395	2299	964	0.01	2.38	407.03
OTSEGO	2.82	0.19	3.01	1014	210	1224	1013	0.00	1.21	406.97
PUTNAM	4.46	0.30	4.77	1607	333	1940	231	0.02	8.40	406.78
QUEENS	51.65	3.52	55.17	18593	3856	22449	108	0.51	207.86	406.90
RENSSELAER	6.91	0.47	7.38	2487	516	3003	665	0.01	4.52	407.00
RICHMOND	13.82	0.94	14.76	4974	1032	6006	58	0.25	103.55	406.91
ROCKLAND	13.56	0.93	14.49	4883	1013	5896	176	0.08	33.50	406.91
ST LAWRENCE	4.87	0.33	5.21	1754	364	2118	2768	0.00	0.77	406.85
SARATOGA	7.00	0.48	7.48	2521	523	3044	818	0.01	3.72	407.01
SCHENECTADY	7.93	0.54	8.47	2854	592	3446	207	0.04	16.65	406.91
SCHOHARIE	1.49	0.10	1.59	537	111	648	624	0.00	1.04	406.40
SCHUYLER	0.90	0.06	0.96	322	67	389	330	0.00	1.18	406.66
SENECA	1.62	0.11	1.73	583	121	704	330	0.01	2.13	407.19
STEUBEN	4.80	0.33	5.13	1728	358	2086	1410	0.00	1.48	406.73
SUFFOLK	67.19	4.58	71.77	24189	5017	29206	929	0.08	31.44	406.91
SULLIVAN	3.65	0.25	3.90	1315	273	1588	988	0.00	1.61	406.92
TIOGA	2.52	0.17	2.69	906	188	1094	524	0.01	2.09	406.93
TOMPKINS	3.74	0.26	4.00	1347	279	1626	482	0.01	3.37	406.89
ULSTER	8.23	0.56	8.80	2964	615	3579	1141	0.01	3.14	406.88
WARREN	3.14	0.21	3.36	1132	235	1367	887	0.00	1.54	407.00
WASHINGTON	2.53	0.17	2.70	910	189	1099	836	0.00	1.31	406.86
WAYNE	4.61	0.31	4.93	1661	344	2005	606	0.01	3.31	406.82
WESTCHESTER	43.21	2.95	46.15	15555	3226	18781	443	0.10	42.40	406.92
WYOMING	2.03	0.14	2.17	731	152	883	598	0.00	1.48	407.17
YATES	1.20	0.08	1.28	432	90	522	343	0.00	1.52	407.08

	ENERGY CONSUMPTION, 10E12 BTU/YR			NOX EMISSIONS, TPY			LAND AREA SQ.ML	ENERGY DENSITY, 10E12BTU/ YR-SQ.ML	EMISSION DENSITY, TPY/SQ.ML	EMN/ENR COEFF.
STATE/COUNTY	GASOLINE	DIESEL	TOTAL	GASOLINE	DIESEL	TOTAL				
PENNSYLVANIA	215.49	36.35	251.84	77578	39800	117378	18036	0.01	6.51	466.08
BERKS	17.36	2.93	20.29	6251	3207	9458	862	0.02	10.97	466.11
BRADFORD	2.86	0.48	3.34	1030	528	1558	1148	0.00	1.36	465.86
BUCKS	26.02	4.39	30.41	9367	4805	14172	614	0.05	23.08	466.07
CARBON	2.87	0.48	3.35	1033	530	1563	404	0.01	3.87	465.95
CENTRE	4.84	0.82	5.66	1742	894	2636	1115	0.01	2.36	466.00
CLINTON	1.84	0.31	2.16	664	341	1005	899	0.00	1.12	466.18
COLUMBIA	3.52	0.59	4.11	1267	650	1917	484	0.01	3.96	466.21
DAUPHIN	13.55	2.29	15.84	4878	2502	7380	518	0.03	14.25	466.03
LACKAWANNA	10.08	1.70	11.78	3628	1861	5489	454	0.03	12.09	466.02
LEBANON	6.02	1.01	7.03	2166	1111	3277	363	0.02	9.03	466.10
LEHIGH	13.96	2.35	16.31	5025	2578	7603	348	0.05	21.85	466.08
LUZERNE	16.26	2.74	19.00	5853	3002	8855	886	0.02	9.99	466.06
LYCOMING	6.02	1.02	7.04	2167	1112	3279	1216	0.01	2.70	466.02
MONROE	3.93	0.66	4.60	1416	726	2142	611	0.01	3.51	466.11
MONTGOMERY	36.63	6.18	42.81	13186	6765	19951	496	0.09	40.22	466.07
MONTOUR	0.88	0.15	1.03	317	163	480	130	0.01	3.69	466.41
NORTHAMPTON	13.61	2.30	15.91	4900	2514	7414	376	0.04	19.72	466.08
NORTHCUMBRLND	5.15	0.87	6.02	1853	951	2804	453	0.01	6.19	466.16
PIKE	9.52	1.61	11.13	3427	1758	5185	542	0.02	9.57	466.00
POTTER	0.85	0.14	1.00	307	158	465	1092	0.00	0.43	466.34
SCHUYLKILL	8.28	1.40	9.68	2982	1530	4512	784	0.01	5.76	466.10
SNYDER	1.77	0.30	2.07	637	327	964	327	0.01	2.95	466.31
SULLIVAN	0.33	0.06	0.39	119	61	180	478	0.00	0.38	466.00
SUSQUEHANNA	1.88	0.32	2.20	678	348	1026	833	0.00	1.23	466.31
TIOGA	2.04	0.34	2.39	735	377	1112	1146	0.00	0.97	466.11
UNION	1.68	0.28	1.96	604	310	914	318	0.01	2.87	466.01
WAYNE	2.27	0.38	2.66	818	420	1238	741	0.00	1.67	466.09
WYOMING	1.47	0.25	1.71	528	271	799	398	0.00	2.01	466.37
RHODE ISLAND	45.53	3.49	49.01	16389	3820	20209	1050	0.05	19.25	412.31
BRISTOL	2.28	0.17	2.45	820	191	1011	25	0.10	40.44	412.21
KENT	8.26	0.63	8.89	2973	693	3666	173	0.05	21.19	412.26
NEWPORT	4.00	0.31	4.31	1442	336	1778	115	0.04	15.46	412.39
PROVIDENCE	26.13	2.00	28.13	9405	2192	11597	416	0.07	27.88	412.31
WASHINGTON	4.86	0.37	5.23	1749	408	2157	321	0.02	6.72	412.34
VERMONT	29.60	4.07	33.68	10657	4456	15113	9266	0.00	1.63	448.77
ADDISON	1.60	0.22	1.82	577	241	818	784	0.00	1.04	448.79
BENNINGTON	1.97	0.27	2.24	708	296	1004	672	0.00	1.49	448.65
CALEDONIA	1.43	0.20	1.63	515	215	730	612	0.00	1.19	448.50
CHITTENDEN	6.24	0.86	7.10	2246	940	3186	533	0.01	5.98	448.83
ESSEX	0.31	0.04	0.36	113	47	160	663	0.00	0.24	446.93
FRANKLIN	1.74	0.24	1.97	625	261	886	660	0.00	1.34	448.67
GRAND ISLE	0.28	0.04	0.32	101	42	143	83	0.00	1.72	449.67
LAMOILLE	1.06	0.15	1.20	380	159	539	474	0.00	1.14	448.79
ORANGE	1.27	0.17	1.44	456	191	647	690	0.00	0.94	449.09
ORLEANS	1.30	0.18	1.48	469	196	665	715	0.00	0.93	448.30
RUTLAND	3.43	0.47	3.90	1236	517	1753	927	0.00	1.89	448.96
WASHINGTON	3.19	0.44	3.63	1148	480	1628	707	0.01	2.30	448.70
WINDHAM	2.42	0.33	2.75	871	364	1235	784	0.00	1.58	448.66
WINDSOR	3.37	0.46	3.83	1212	507	1719	962	0.00	1.79	449.01

	ENERGY CONSUMPTION 10E12 BTU/YR			NOX EMISSIONS, TPY			LAND AREA, SQ.ML	ENERGY DENSITY, 10E12BTU/ YR-SQ.ML	EMISSION DENSITY, TPY/SQ.ML	EMN/ENR COEFF.
STATE/COUNTY	N.GAS	D.OIL	TOTAL	N.GAS	D.OIL	TOTAL				
CONNECTICUT	31.78	102.60	134.38	1589	6740	8329	4863	0.03	1.71	61.98
FAIRFIELD	8.26	26.65	34.91	413	1751	2164	626	0.06	3.46	61.99
HARTFORD	8.26	26.67	34.93	413	1752	2165	739	0.05	2.93	61.98
LITCHFIELD	1.60	5.17	6.77	80	340	420	925	0.01	0.45	62.04
MIDDLESEX	1.32	4.26	5.58	66	280	346	372	0.02	0.93	62.01
NEW HAVEN	7.79	25.14	32.93	390	1652	2042	604	0.05	3.38	62.01
NEW LONDON	2.44	7.87	10.31	122	517	639	667	0.02	0.96	61.98
TOLLAND	1.17	3.79	4.96	59	249	308	416	0.01	0.74	62.10
WINDHAM	0.94	3.05	3.99	47	200	247	514	0.01	0.48	61.90
MASSACHUSETTS	80.06	146.45	226.51	4003	9621	13624	7283	0.03	1.87	60.15
BERKSHIRE	2.08	3.81	5.89	104	250	354	941	0.01	0.38	60.10
BRISTOL	6.81	12.45	19.26	341	818	1159	554	0.03	2.09	60.18
ESSEX	9.09	16.63	25.72	455	1092	1547	494	0.05	3.13	60.15
FRANKLIN	0.92	1.69	2.61	46	111	157	708	0.00	0.22	60.15
HAMPDEN	6.35	11.63	17.98	318	764	1082	619	0.03	1.75	60.18
HAMPSHIRE	1.99	3.64	5.63	100	239	339	529	0.01	0.64	60.21
MIDDLESEX	19.70	36.00	55.70	985	2365	3350	825	0.07	4.06	60.14
NORFOLK	8.70	15.92	24.62	435	1046	1481	394	0.06	3.76	60.15
PLYMOUTH	5.82	10.65	16.47	291	700	991	654	0.03	1.52	60.17
SUFFOLK	9.32	17.06	26.38	466	1121	1587	56	0.47	28.34	60.16
WORCHESTER	9.28	16.97	26.25	464	1115	1579	1509	0.02	1.05	60.15
NEW HAMPSHIRE	3.82	24.71	28.53	191	1623	1814	9028	0.00	0.20	63.58
BELKNAP	0.18	1.15	1.33	9	76	85	400	0.00	0.21	63.91
CARROL	0.12	0.75	0.87	6	49	55	938	0.00	0.06	63.22
CHESHIRE	0.26	1.67	1.93	13	110	123	715	0.00	0.17	63.73
COOS	0.15	0.94	1.09	8	62	70	1820	0.00	0.04	64.22
GRAFTON	0.27	1.77	2.04	14	116	130	1732	0.00	0.08	63.73
HILLSBOROUGH	1.14	7.42	8.56	57	487	544	887	0.01	0.61	63.55
MERRIMACK	0.41	2.64	3.05	21	173	194	930	0.00	0.21	63.56
ROCKINGHAM	0.79	5.11	5.90	40	336	376	691	0.01	0.54	63.73
STRAFFORD	0.35	2.29	2.64	18	150	168	376	0.01	0.45	63.64
SULLIVAN	0.15	0.97	1.12	8	64	72	539	0.00	0.13	64.29
NEW JERSEY	107.34	103.98	211.32	5367	6831	12198	5270	0.04	2.31	57.72
BERGEN	14.59	14.13	28.72	730	928	1658	234	0.12	7.09	57.73
BURLINGTON	6.25	6.06	12.31	313	398	711	819	0.02	0.87	57.76
ESSEX	14.68	14.22	28.90	734	934	1668	130	0.22	12.83	57.72
HUDSON	9.61	9.31	18.92	481	612	1093	47	0.40	23.26	57.77
HUNTERDON	1.51	1.46	2.97	76	96	172	423	0.01	0.41	57.91
MERCER	5.31	5.15	10.46	266	338	604	228	0.05	2.65	57.74
MIDDLESEX	10.28	9.96	20.24	514	654	1168	312	0.06	3.74	57.71
MONMOUTH	8.68	8.41	17.09	434	552	986	476	0.04	2.07	57.69
MORRIS	7.04	6.82	13.86	352	448	800	468	0.03	1.71	57.72
OCEAN	5.97	5.79	11.76	299	380	679	642	0.02	1.06	57.74
PASSAIC	7.73	7.48	15.21	387	491	878	192	0.08	4.57	57.73
SOMERSET	3.51	3.40	6.91	176	223	399	307	0.02	1.30	57.74
SUSSEX	2.01	1.94	3.95	101	127	228	527	0.01	0.43	57.72
UNION	8.71	8.43	17.14	436	554	990	103	0.17	9.61	57.76
WARREN	1.46	1.42	2.88	73	93	166	362	0.01	0.46	57.64

	ENERGY CONSUMPTION 10E12 BTU/YR			NOX EMISSIONS, TPY				ENERGY		
STATE/COUNTY	N.GAS	D.OIL	TOTAL	N.GAS	D.OIL	TOTAL	LAND AREA, SQ.MI	DENSITY, 10E12BTU/ YR-SQ.MI	EMISSION DENSITY, TPY/SQ.MI	EMN/ENR COEFF.
NEW YORK	310.40	248.21	558.61	15520	16306	31826	44908	0.01	0.71	56.97
ALBANY	5.19	4.15	9.34	260	273	533	526	0.02	1.01	57.07
ALLEGANY	0.92	0.74	1.66	46	49	95	1047	0.00	0.09	57.23
BRONX	21.23	16.97	38.20	1062	1115	2177	41	0.93	53.10	56.99
BROOME	3.89	3.11	7.00	195	204	399	714	0.01	0.56	57.00
CAYUGA	1.47	1.17	2.64	74	77	151	698	0.00	0.22	57.20
CHEMUNG	1.78	1.43	3.21	89	94	183	415	0.01	0.44	57.01
CHENANGO	0.89	0.71	1.60	45	47	92	903	0.00	0.10	57.50
CLINTON	1.47	1.17	2.64	74	77	151	1059	0.00	0.14	57.20
COLUMBIA	1.08	0.87	1.95	54	57	111	645	0.00	0.17	56.92
CORTLAND	0.89	0.71	1.60	45	47	92	502	0.00	0.18	57.50
DELEWARE	0.86	0.69	1.55	43	45	88	1443	0.00	0.06	56.77
DUTCHESS	4.46	3.57	8.03	223	235	458	813	0.01	0.56	57.04
ERIE	18.42	14.73	33.15	921	968	1889	1058	0.03	1.79	56.98
ESSEX	0.67	0.54	1.21	34	35	69	1823	0.00	0.04	57.02
FRANKLIN	0.83	0.66	1.49	42	43	85	1674	0.00	0.05	57.05
FULTON	0.99	0.79	1.78	50	52	102	498	0.00	0.20	57.30
GENESEE	1.08	0.87	1.95	54	57	111	501	0.00	0.22	56.92
GREENE	0.73	0.59	1.32	37	39	76	653	0.00	0.12	57.58
HAMILTON	0.10	0.08	0.18	5	5	10	1735	0.00	0.01	55.56
HERKIMER	1.21	0.97	2.18	61	64	125	1435	0.00	0.09	57.34
JEFFERSON	1.59	1.27	2.86	80	83	163	1294	0.00	0.13	56.99
KINGS	40.51	32.39	72.90	2026	2128	4154	70	1.04	59.34	56.98
LEWIS	0.45	0.36	0.81	23	24	47	1291	0.00	0.04	58.02
LIVINGSTON	1.02	0.82	1.84	51	54	105	638	0.00	0.16	57.07
MADISON	1.18	0.94	2.12	59	62	121	661	0.00	0.18	57.08
MONROE	12.75	10.19	22.94	638	669	1307	675	0.03	1.94	56.97
MONTGOMERY	0.96	0.76	1.72	48	50	98	408	0.00	0.24	56.98
NASSAU	24.00	19.19	43.19	1200	1261	2461	289	0.15	8.52	56.98
NEW YORK	25.91	20.72	46.63	1296	1361	2657	23	2.03	115.52	56.98
ONEIDA	4.59	3.67	8.26	230	241	471	1223	0.01	0.39	57.02
ONONDAGA	8.41	6.73	15.14	421	442	863	794	0.02	1.09	57.00
ONTARIO	1.63	1.30	2.93	82	85	167	651	0.00	0.26	57.00
ORANGE	4.72	3.77	8.49	236	248	484	833	0.01	0.58	57.01
ORLEANS	0.70	0.56	1.26	35	37	72	396	0.00	0.18	57.14
OSWEGO	2.07	1.66	3.73	104	109	213	964	0.00	0.22	57.10
OTSEGO	1.08	0.87	1.95	54	57	111	1013	0.00	0.11	56.89
PUTNAM	1.40	1.12	2.52	70	74	144	231	0.01	0.62	57.14
QUEENS	34.32	27.44	61.76	1716	1803	3519	108	0.57	32.58	56.98
RENSSELAER	2.77	2.22	4.99	139	146	285	665	0.01	0.43	57.11
RICHMOND	6.41	5.12	11.53	321	336	657	58	0.20	11.33	56.98
ROCKLAND	4.72	3.77	8.49	236	248	484	176	0.05	2.75	57.01
ST LAWRENCE	2.07	1.66	3.73	104	109	213	2768	0.00	0.08	57.10
SARATOGA	2.80	2.24	5.04	140	147	287	818	0.01	0.35	56.94
SCHENECTADY	2.71	2.17	4.88	136	143	279	207	0.02	1.35	57.17
SCHOHARIE	0.54	0.43	0.97	27	28	55	624	0.00	0.09	56.70
SCHUYLER	0.32	0.25	0.57	16	16	32	330	0.00	0.10	56.14
SENECA	0.61	0.48	1.09	31	32	63	330	0.00	0.19	57.80
STEUBEN	1.78	1.43	3.21	89	94	183	1410	0.00	0.13	57.01
SUFFOLK	23.30	18.63	41.93	1165	1224	2389	929	0.05	2.57	56.98
SULLIVAN	1.18	0.94	2.12	59	62	121	988	0.00	0.12	57.08
TIOGA	0.89	0.71	1.60	45	47	92	524	0.00	0.18	57.50
TOMPKINS	1.59	1.27	2.86	80	83	163	482	0.01	0.34	56.94
ULSTER	2.87	2.29	5.16	144	150	294	1141	0.00	0.26	56.98
WARREN	0.99	0.79	1.78	50	52	102	887	0.00	0.11	57.30
WASHINGTON	0.99	0.79	1.78	50	52	102	836	0.00	0.12	57.30
WAYNE	1.56	1.25	2.81	78	82	160	606	0.00	0.26	56.94
WESTCHESTER	15.74	12.59	28.33	787	827	1614	443	0.06	3.64	56.97
WYOMING	0.73	0.59	1.32	37	39	76	598	0.00	0.13	57.58
YATES	0.38	0.31	0.69	19	20	39	343	0.00	0.11	56.52

	ENERGY CONSUMPTION 10E12 BTU/YR			NOX EMISSIONS, TPY				ENERGY		
STATE/COUNTY	N.GAS	D.OIL	TOTAL	N.GAS	D.OIL	TOTAL	LAND AREA, SQ.MI	DENSITY, 10E12BTU/ YR-SQ.MI	EMISSION DENSITY, TPY/SQ.MI	EMN/ENR COEFF.
PENNSYLVANIA	96.53	60.74	157.27	4827	3990	8817	18036	0.01	0.49	56.06
BERKS	7.73	4.88	12.61	387	321	708	862	0.01	0.82	56.15
BRADFORD	1.56	0.98	2.54	78	64	142	1148	0.00	0.12	55.91
BUCKS	11.87	7.50	19.37	594	493	1087	614	0.03	1.77	56.12
CARBON	1.32	0.84	2.16	66	55	121	404	0.01	0.30	56.02
CENTRE	2.79	1.76	4.55	140	116	256	1115	0.00	0.23	56.26
CLINTON	0.97	0.61	1.58	49	40	89	899	0.00	0.10	56.33
COLUMBIA	1.53	0.97	2.50	77	64	141	484	0.01	0.29	56.40
DAUPHIN	5.76	3.64	9.40	288	239	527	518	0.02	1.02	56.06
LACKAWANNA	5.64	3.56	9.20	282	234	516	454	0.02	1.14	56.09
LEBANON	2.73	1.73	4.46	137	114	251	363	0.01	0.69	56.28
LEHIGH	6.79	4.29	11.08	340	282	622	348	0.03	1.79	56.14
LUZERNE	8.49	5.36	13.85	425	352	777	886	0.02	0.88	56.10
LYCOMING	2.94	1.70	4.64	147	112	259	1216	0.00	0.21	55.82
MONROE	1.86	1.08	2.94	93	71	164	611	0.00	0.27	55.78
MONTGOMERY	15.92	10.06	25.98	796	661	1457	496	0.05	2.94	56.08
MONTOUR	0.41	0.26	0.67	21	17	38	130	0.01	0.29	56.72
NORTHAMPTON	5.58	3.53	9.11	279	232	511	376	0.02	1.36	56.09
NORTHCUMBRLND	2.50	1.58	4.08	125	104	229	453	0.01	0.51	56.13
PIKE	0.44	0.28	0.72	22	18	40	542	0.00	0.07	55.56
POTTER	0.44	0.28	0.72	22	18	40	1092	0.00	0.04	55.56
SCHUYLKILL	3.97	2.51	6.48	199	165	364	784	0.01	0.46	56.17
SYNDER	0.82	0.52	1.34	41	34	75	327	0.00	0.23	55.97
SULLIVAN	0.15	0.09	0.24	8	6	14	478	0.00	0.03	58.33
SUSQUEHANNA	0.94	0.59	1.53	47	39	86	833	0.00	0.10	56.21
TIOGA	1.03	0.65	1.68	52	43	95	1146	0.00	0.08	56.55
UNION	0.82	0.52	1.34	41	34	75	318	0.00	0.24	55.97
WAYNE	0.88	0.56	1.44	44	37	81	741	0.00	0.11	56.25
WYOMING	0.65	0.41	1.06	33	27	60	398	0.00	0.15	56.60
RHODE ISLAND	13.70	28.40	42.10	685	1866	2551	1050	0.04	2.43	60.59
BRISTOL	0.68	1.41	2.09	34	93	127	25	0.08	5.08	60.77
KENT	2.23	4.62	6.85	112	304	416	173	0.04	2.40	60.73
NEWPORT	1.18	2.44	3.62	59	160	219	115	0.03	1.90	60.50
PROVIDENCE	8.26	17.13	25.39	413	1125	1538	416	0.06	3.70	60.58
WASHINGTON	1.35	2.80	4.15	68	184	252	321	0.01	0.79	60.72
VERMONT	1.10	18.51	19.61	55	1216	1271	9266	0.00	0.14	64.81
ADDISON	0.06	1.06	1.12	3	70	73	784	0.00	0.09	65.18
BENNINGTON	0.07	1.21	1.28	4	79	83	672	0.00	0.12	64.84
CALEDONIA	0.06	0.93	0.99	3	61	64	612	0.00	0.10	64.65
CHITTENDEN	0.25	4.18	4.43	13	275	288	533	0.01	0.54	65.01
ESSEX	0.01	0.23	0.24	1	15	16	663	0.00	0.02	66.67
FRANKLIN	0.07	1.26	1.33	4	83	87	660	0.00	0.13	65.41
GRAND ISLE	0.01	0.17	0.18	1	11	12	83	0.00	0.14	66.67
LAMOILLE	0.04	0.61	0.65	2	40	42	474	0.00	0.09	64.62
ORANGE	0.05	0.82	0.87	3	54	57	690	0.00	0.08	65.52
ORLEANS	0.05	0.85	0.90	3	56	59	715	0.00	0.08	65.56
RUTLAND	0.13	2.11	2.24	7	139	146	927	0.00	0.16	65.18
WASHINGTON	0.11	1.89	2.00	6	124	130	707	0.00	0.18	65.00
WINDHAM	0.08	1.34	1.42	4	88	92	784	0.00	0.12	64.79
WINDSOR	0.11	1.85	1.96	6	122	128	962	0.00	0.13	65.31

COMMERCIAL SECTOR

STATE/COUNTY	ENERGY CONSUMPTION, 10E12 BTU/YR				NOX EMISSIONS, TPY				LAND AREA, SQ.ML	ENERGY DENSITY, 10E12BTU/ YR-SQ.ML	EMISSION DENSITY, TPY/SQ.ML	EMN/ENR COEFF.
	N.GAS	D.OIL	R.OIL	TOTAL	N.GAS	D.OIL	R.OIL	TOTAL				
CONNECTICUT	17.09	33.29	3.60	53.98	1196	1997	720	3913	4863	0.01	0.80	72.49
FAIRFIELD	4.44	8.65	0.93	14.02	311	519	186	1016	626	0.02	1.62	72.47
HARTFORD	4.44	8.65	0.94	14.03	311	519	188	1018	739	0.02	1.38	72.56
LITCHFIELD	0.86	1.68	0.18	2.72	60	101	36	197	925	0.00	0.21	72.43
MIDDLESEX	0.71	1.38	0.15	2.24	50	83	30	163	372	0.01	0.44	72.77
NEW HAVEN	4.19	8.16	0.88	13.23	293	490	176	959	604	0.02	1.59	72.49
NEW LONDON	1.31	2.55	0.28	4.14	92	153	56	301	667	0.01	0.45	72.71
TOLLAND	0.63	1.23	0.13	1.99	44	74	26	144	416	0.00	0.35	72.36
WINDHAM	0.51	0.99	0.11	1.61	36	59	22	117	514	0.00	0.23	72.67
MASSACHUSETTS	46.23	51.01	23.30	120.54	3236	3061	4660	10957	7283	0.02	1.50	90.90
BERKSHIRE	1.20	1.33	0.61	3.14	84	80	122	286	941	0.00	0.30	91.08
BRISTOL	3.93	4.34	1.98	10.25	275	260	396	931	554	0.02	1.68	90.83
ESSEX	5.24	5.80	2.65	13.69	367	348	530	1245	494	0.03	2.52	90.94
FRANKLIN	0.53	0.59	0.27	1.39	37	35	54	126	708	0.00	0.18	90.65
HAMPDEN	3.67	4.05	1.85	9.57	257	243	370	870	619	0.02	1.41	90.91
HAMPSHIRE	1.15	1.27	0.58	3.00	81	76	116	273	529	0.01	0.52	91.00
MIDDLESEX	11.40	12.50	5.70	29.60	798	750	1140	2688	825	0.04	3.26	90.81
NORFOLK	5.02	5.55	2.54	13.11	351	333	508	1192	394	0.03	3.03	90.92
PLYMOUTH	3.36	3.71	1.70	8.77	235	223	340	798	654	0.01	1.22	90.99
SUFFOLK	5.38	5.95	2.72	14.05	377	357	544	1278	56	0.25	22.82	90.96
WORCHESTER	5.35	5.92	2.70	13.97	375	355	540	1270	1509	0.01	0.84	90.91
NEW HAMPSHIRE	3.39	2.61	0.09	6.09	237	157	18	412	9028	0.00	0.05	67.65
BELKNAP	0.16	0.12	0.00	0.28	11	7	0	18	400	0.00	0.05	64.29
CARROL	0.10	0.08	0.00	0.18	7	5	0	12	938	0.00	0.01	66.67
CHESHIRE	0.23	0.18	0.01	0.42	16	11	2	29	715	0.00	0.04	69.05
COOS	0.13	0.10	0.00	0.23	9	6	0	15	1820	0.00	0.01	65.22
GRAFTON	0.24	0.19	0.01	0.44	17	11	2	30	1732	0.00	0.02	68.18
HILLSBOROUGH	1.02	0.78	0.03	1.83	71	47	6	124	887	0.00	0.14	67.76
MERRIMACK	0.36	0.28	0.01	0.65	25	17	2	44	930	0.00	0.05	67.69
ROCKINGHAM	0.70	0.54	0.02	1.26	49	32	4	85	691	0.00	0.12	67.46
STRAFFORD	0.32	0.24	0.01	0.57	22	14	2	38	376	0.00	0.10	66.67
SULLIVAN	0.13	0.10	0.00	0.23	9	6	0	15	539	0.00	0.03	65.22
NEW JERSEY	45.01	35.15	56.25	136.41	3151	2109	11250	16510	5270	0.03	3.13	121.03
BERGEN	6.12	4.78	7.65	18.55	428	287	1530	2245	234	0.08	9.59	121.02
BURLINGTON	2.62	2.05	3.28	7.95	183	123	656	962	819	0.01	1.17	121.01
ESSEX	6.16	4.80	7.69	18.65	431	288	1538	2257	130	0.14	17.36	121.02
HUDSON	4.03	3.14	5.03	12.20	282	188	1006	1476	47	0.26	31.40	120.98
HUNTERDON	0.63	0.50	0.79	1.92	44	30	158	232	423	0.00	0.55	120.83
MERCER	2.23	1.74	2.78	6.75	156	104	556	816	228	0.03	3.58	120.89
MIDDLESEX	4.31	3.37	5.39	13.07	302	202	1078	1582	312	0.04	5.07	121.04
MONMOUTH	3.64	2.84	4.55	11.03	255	170	910	1335	476	0.02	2.80	121.03
MORRIS	2.95	2.30	3.69	8.94	207	138	738	1083	468	0.02	2.31	121.14
OCEAN	2.51	1.96	3.13	7.60	176	118	626	920	642	0.01	1.43	121.05
PASSAIC	3.24	2.53	4.05	9.82	227	152	810	1189	192	0.05	6.19	121.08
SOMERSET	1.47	1.15	1.84	4.46	103	69	368	540	307	0.01	1.76	121.08
SUSSEX	0.84	0.66	1.05	2.55	59	40	210	309	527	0.00	0.59	121.18
UNION	3.65	2.85	4.56	11.06	256	171	912	1339	103	0.11	13.00	121.07
WARREN	0.61	0.48	0.77	1.86	43	29	154	226	362	0.01	0.62	121.51

	ENERGY CONSUMPTION, 10E12 BTU/YR				NOX EMISSIONS, TPY							
STATE/COUNTY	N.GAS	D.OIL	R.OIL	TOTAL	N.GAS	D.OIL	R.OIL	TOTAL	LAND AREA, SQ.MI	ENERGY DENSITY, 10E12BTU/ YR-SQ.MI	EMISSION DENSITY, TPY/SQ.MI	EMN/ENR COEFF.
NEW YORK	142.12	84.06	138.29	364.47	9948	5044	27658	42650	44908	0.01	0.95	117.02
ALBANY	2.38	1.41	2.31	6.10	167	85	462	714	526	0.01	1.36	117.05
ALLEGANY	0.42	0.25	0.41	1.08	29	15	82	126	1047	0.00	0.12	116.67
BRONX	9.73	5.75	9.46	24.94	681	345	1892	2918	41	0.61	71.17	117.00
BROOME	1.78	1.05	1.73	4.56	125	63	346	534	714	0.01	0.75	117.11
CAYUGA	0.67	0.40	0.65	1.72	47	24	130	201	698	0.00	0.29	116.86
CHEMUNG	0.82	0.48	0.80	2.10	57	29	160	246	415	0.01	0.59	117.14
CHENANGO	0.41	0.24	0.40	1.05	29	14	80	123	903	0.00	0.14	117.14
CLINTON	0.67	0.40	0.65	1.72	47	24	130	201	1059	0.00	0.19	116.86
COLUMBIA	0.50	0.29	0.48	1.27	35	17	96	148	645	0.00	0.23	116.54
CORTLAND	0.41	0.24	0.40	1.05	29	14	80	123	502	0.00	0.25	117.14
DELEWARE	0.39	0.23	0.38	1.00	27	14	76	117	1443	0.00	0.08	117.00
DUTCHESS	2.05	1.21	1.99	5.25	144	73	398	615	813	0.01	0.76	117.14
ERIE	8.44	4.99	8.21	21.64	591	299	1642	2532	1058	0.02	2.39	117.01
ESSEX	0.31	0.18	0.30	0.79	22	11	60	93	1823	0.00	0.05	117.72
FRANKLIN	0.38	0.22	0.37	0.97	27	13	74	114	1674	0.00	0.07	117.53
FULTON	0.45	0.27	0.44	1.16	32	16	88	136	498	0.00	0.27	117.24
GENESEE	0.50	0.29	0.48	1.27	35	17	96	148	501	0.00	0.30	116.54
GREENE	0.34	0.20	0.33	0.87	24	12	66	102	653	0.00	0.16	117.24
HAMILTON	0.04	0.03	0.04	0.11	3	2	8	13	1735	0.00	0.01	118.18
HERKIMER	0.56	0.33	0.54	1.43	39	20	108	167	1435	0.00	0.12	116.78
JEFFERSON	0.73	0.43	0.71	1.87	51	26	142	219	1294	0.00	0.17	117.11
KINGS	18.57	10.97	18.05	47.59	1300	658	3610	5568	70	0.68	79.54	117.00
LEWIS	0.20	0.12	0.20	0.52	14	7	40	61	1291	0.00	0.05	117.31
LIVINGSTON	0.47	0.28	0.45	1.20	33	17	90	140	638	0.00	0.22	116.67
MADISON	0.54	0.32	0.53	1.39	38	19	106	163	661	0.00	0.25	117.27
MONROE	5.84	3.45	5.68	14.97	409	207	1136	1752	675	0.02	2.60	117.03
MONTGOMERY	0.44	0.26	0.43	1.13	31	16	86	133	408	0.00	0.33	117.70
NASSAU	11.00	6.50	10.69	28.19	770	390	2138	3298	289	0.10	11.41	116.99
NEW YORK	11.88	7.02	11.54	30.44	832	421	2308	3561	23	1.32	154.83	116.98
ONEIDA	2.10	1.24	2.04	5.38	147	74	408	629	1223	0.00	0.51	116.91
ONONDAGA	3.68	2.28	3.75	9.71	258	137	750	1145	794	0.01	1.44	117.92
ONTARIO	0.75	0.44	0.72	1.91	53	26	144	223	651	0.00	0.34	116.75
ORANGE	2.16	1.28	2.10	5.54	151	77	420	648	833	0.01	0.78	116.97
ORLEANS	0.32	0.19	0.31	0.82	22	11	62	95	396	0.00	0.24	115.85
OSWEGO	0.94	0.57	0.92	2.43	66	34	184	284	964	0.00	0.29	116.87
OTSEGO	0.50	0.29	0.48	1.27	35	17	96	148	1013	0.00	0.15	116.54
PUTNAM	0.64	0.38	0.62	1.64	45	23	124	192	231	0.01	0.83	117.07
QUEENS	15.73	9.29	15.29	40.31	1101	557	3058	4716	108	0.37	43.67	116.99
RENSSELAER	1.27	0.75	1.24	3.26	89	45	248	382	665	0.00	0.57	117.18
RICHMOND	2.94	1.73	2.85	7.52	206	104	570	880	58	0.13	15.17	117.02
ROCKLAND	2.16	1.28	2.10	5.54	151	77	420	648	176	0.03	3.68	116.97
ST LAWRENCE	0.95	0.56	0.92	2.43	67	34	184	285	2768	0.00	0.10	117.28
SARATOGA	1.29	0.76	1.25	3.30	90	46	250	386	818	0.00	0.47	116.97
SCHENECTADY	1.24	0.73	1.21	3.18	87	44	242	373	207	0.02	1.80	117.30
SCHOHARIE	0.25	0.15	0.24	0.64	18	9	48	75	624	0.00	0.12	117.19
SCHUYLER	0.15	0.09	0.14	0.38	11	5	28	44	330	0.00	0.13	115.79
SENECA	0.28	0.16	0.27	0.71	20	10	54	84	330	0.00	0.25	118.31
STEUBEN	0.82	0.48	0.80	2.10	57	29	160	246	1410	0.00	0.17	117.14
SUFFOLK	10.68	6.31	10.38	27.37	748	379	2076	3203	929	0.03	3.45	117.03
SULLIVAN	0.54	0.32	0.53	1.39	38	19	106	163	988	0.00	0.16	117.27
TIOGA	0.41	0.24	0.40	1.05	29	14	80	123	524	0.00	0.23	117.14
TOMPKINS	0.73	0.43	0.71	1.87	51	26	142	219	482	0.00	0.45	117.11
ULSTER	1.31	0.78	1.28	3.37	92	47	256	395	1141	0.00	0.35	117.21
WARREN	0.45	0.27	0.44	1.16	32	16	88	136	887	0.00	0.15	117.24
WASHINGTON	0.45	0.27	0.44	1.16	32	16	88	136	836	0.00	0.16	117.24
WAYNE	0.72	0.42	0.70	1.84	50	25	140	215	606	0.00	0.35	116.85
WESTCHESTER	7.22	4.26	7.01	18.49	505	256	1402	2163	443	0.04	4.88	116.98
WYOMING	0.34	0.20	0.33	0.87	24	12	66	102	598	0.00	0.17	117.24
YATES	0.18	0.10	0.17	0.45	13	6	34	53	343	0.00	0.15	117.78

STATE/COUNTY	ENERGY CONSUMPTION, 10E12 BTU/YR				NOX EMISSIONS, TPY				LAND AREA, SQ.MI	ENERGY DENSITY, 10E12BTU/ YR-SQ.MI	EMISSION DENSITY, TPY/SQ.MI	EMM/EMR COEFF.
	N.GAS	D.OIL	R.OIL	TOTAL	N.GAS	D.OIL	R.OIL	TOTAL				
PENNSYLVANIA	37.24	10.60	6.59	54.43	2607	636	1318	4561	10036	0.00	0.25	83.80
BERKS	2.99	0.85	0.53	4.37	209	51	106	366	862	0.01	0.42	83.75
BRADFORD	0.60	0.17	0.11	0.88	42	10	22	74	1148	0.00	0.06	84.09
BUCKS	4.59	1.30	0.81	6.70	321	78	162	561	614	0.01	0.91	83.73
CARBON	0.51	0.15	0.09	0.75	36	9	18	63	404	0.00	0.16	84.00
CENTRE	1.08	0.31	0.19	1.58	76	19	38	133	1115	0.00	0.12	84.18
CLINTON	0.37	0.11	0.07	0.55	26	7	14	47	899	0.00	0.05	85.45
COLUMBIA	0.59	0.17	0.10	0.86	41	10	20	71	484	0.00	0.15	82.56
DAUPHIN	2.22	0.63	0.39	3.24	155	38	78	271	518	0.01	0.52	83.64
LACKAWANNA	2.18	0.62	0.39	3.19	153	37	78	268	454	0.01	0.59	84.01
LEBANON	1.06	0.30	0.19	1.55	74	18	38	130	363	0.00	0.36	83.87
LEHIGH	2.62	0.75	0.46	3.83	183	45	92	320	348	0.01	0.92	83.55
LUZERNE	3.28	0.93	0.58	4.79	230	56	116	402	886	0.01	0.45	83.92
LYCOMING	1.14	0.32	0.20	1.66	80	19	40	139	1216	0.00	0.11	83.73
MONROE	0.66	0.19	0.12	0.97	46	11	24	81	611	0.00	0.13	83.51
MONTGOMERY	6.15	1.75	1.09	8.99	431	105	218	754	496	0.02	1.52	83.87
MONTOUR	0.16	0.05	0.03	0.24	11	3	6	20	130	0.00	0.15	83.33
NORTHAMPTON	2.16	0.61	0.38	3.15	151	37	76	264	376	0.01	0.70	83.81
NORTHCUMBRLND	0.96	0.27	0.17	1.40	67	16	34	117	453	0.00	0.26	83.57
PIKE	0.17	0.05	0.03	0.25	12	3	6	21	542	0.00	0.04	84.00
POTTER	0.17	0.05	0.03	0.25	12	3	6	21	1092	0.00	0.02	84.00
SCHUYLKILL	1.53	0.44	0.27	2.24	107	26	54	187	784	0.00	0.24	83.48
SYNDER	0.32	0.09	0.06	0.47	22	5	12	39	327	0.00	0.12	82.98
SULLIVAN	0.06	0.02	0.01	0.09	4	1	2	7	478	0.00	0.01	77.78
SUSQUEHANNA	0.36	0.10	0.06	0.52	25	6	12	43	833	0.00	0.05	82.69
TIOGA	0.40	0.11	0.07	0.58	28	7	14	49	1146	0.00	0.04	84.48
UNION	0.32	0.09	0.06	0.47	22	5	12	39	318	0.00	0.12	82.98
WAYNE	0.34	0.10	0.06	0.50	24	6	12	42	741	0.00	0.06	84.00
WYOMING	0.25	0.07	0.04	0.36	18	4	8	30	398	0.00	0.08	83.33
RHODE ISLAND	6.30	7.10	1.71	15.11	441	426	342	1209	1050	0.01	1.15	80.01
BRISTOL	0.31	0.35	0.08	0.74	22	21	16	59	25	0.03	2.36	79.73
KENT	1.03	1.16	0.28	2.47	72	70	56	198	173	0.01	1.14	80.16
NEWPORT	0.54	0.61	0.15	1.30	38	37	30	105	115	0.01	0.91	80.77
PROVIDENCE	3.80	4.28	1.03	9.11	266	257	206	729	416	0.02	1.75	80.02
WASHINGTON	0.62	0.70	0.17	1.49	43	42	34	119	321	0.00	0.37	79.87
VERMONT	0.73	2.79	0.67	4.19	51	167	134	352	9266	0.00	0.04	84.01
ADDISON	0.06	0.22	0.06	0.34	4	13	12	29	784	0.00	0.04	85.29
BENNINGTON	0.07	0.25	0.07	0.39	5	15	14	34	672	0.00	0.05	87.18
CALEDONIA	0.01	0.04	0.01	0.06	1	2	2	5	612	0.00	0.01	83.33
CHITTENDEN	0.00	0.01	0.00	0.01	0	1	0	1	533	0.00	0.00	100.00
ESSEX	0.01	0.05	0.01	0.07	1	3	2	6	663	0.00	0.01	85.71
FRANKLIN	0.07	0.26	0.01	0.34	5	16	2	23	660	0.00	0.03	67.65
GRAND ISLE	0.01	0.03	0.01	0.05	1	2	2	5	83	0.00	0.06	100.00
LAMOILLE	0.03	0.12	0.03	0.18	2	7	6	15	474	0.00	0.03	83.33
ORANGE	0.04	0.17	0.04	0.25	3	10	8	21	690	0.00	0.03	84.00
ORLEANS	0.05	0.17	0.05	0.27	4	10	10	24	715	0.00	0.03	88.89
RUTLAND	0.11	0.43	0.11	0.65	8	26	22	56	927	0.00	0.06	86.15
WASHINGTON	0.10	0.39	0.10	0.59	7	23	20	50	707	0.00	0.07	84.75
WINDHAM	0.07	0.27	0.07	0.41	5	16	14	35	784	0.00	0.04	85.37
WINDSOR	0.10	0.38	0.10	0.58	7	23	20	50	962	0.00	0.05	86.21